United States Department of Agriculture

Agricultural Research Service

August 1987

Proceedings of the 43rd Southern Pasture and Forage Crop Improvement Conference

Held at Clemson, South Carolina
April 20-22,1987

United States
Department of
Agriculture

**Agricultural
Research
Service**

Proceedings of the 43rd Southern Pasture and Forage Crop Improvement Conference

Held at Clemson, South Carolina April 20-22,1987

Sponsored by the
Agricultural Experiment Stations
of Alabama, Arkansas, Florida, Georgia,
Kentucky, Louisiana, Mississippi,
North Carolina, Oklahoma, Puerto Rico,
South Carolina, Tennessee, Texas, and Virginia
and the
Agricultural Research Service
U.S. Department of Agriculture

CONTENTS

SERICEA LESPEDEZA, THE UNREALIZED POTENTIAL

Richard E. Joost[1]

INTRODUCTION

Sericea lespedeza (Lespedeza cuneata (Dumont) G. Don) is a warm-season, perennial legume well adapted to the highly weathered soils of the Southeast. Sericea was widely planted for conservation purposes and occasionally used as a hay crop from the time of its introduction in North Carolina in 1896 until cheap fertilizer prices and improved grass varieties replaced it in many areas in the 1950's (Pieters et al., 1950). The recent release of improved quality sericea varieties has opened the door for increases in sericea acreages planted for hay and pasture.

Forage crops are generally consigned to lands incapable of supporting sustained row crop production. In the Southeast, including Puerto Rico, 40% of the total land area or 86 million hectares is occupied by Ultisols. These soils are characterized as highly leached with high clay accumulation in subsurface horizons due to rainfall in excess of evapotranspiration. Acid leaching results in a low base status and subsoil acidity (Buol, 1983). Subsoil acidity manifests itself in the infertility problems including Al and Mn toxicity and deficiencies of Mo and Ca (Adams, 1981).

The effect of excess Al in subsoils is most apparent in roots of sensitive plants. Root systems are stunted due to the disruption of mitosis in root tips (Horst et al., 1983). High levels of soil Al kill the taproot of white clover (Trifolium repens L.) and cause production of thickened secondary roots (Haynes and Ludecke, 1981). The potential of sericea lespedeza lies in its ability to grow on highly weathered, acid, infertile soils. Early field trials of sericea indicated its tolerance to low soil fertility and acid conditions (Pieters et al., 1950).

ALUMINUM TOLERANCE AND ROOT GROWTH IN SERICEA

Results of an Al tolerance screening test of 15 sericea entries indicated that all the sericea entries were superior in Al tolerance to alfalfa based on seedling root growth in 0.5mM Al compared with root growth in Al-free solution. Root length in 0.5 mM Al ranged from 26 to 58% that of root length in 0 Al among the sericea entries compared with 15% for alfalfa (Medicago sativa L.). These results were confirmed by a field study using limed (pH 6.0, 0.05 cmol (1/3 Al^{3+}) kg^{-1}) and unlimed (pH 4.7, 0.7 cmol (1/3 Al^{3+}) kg^{-1}) plots on an Altavista loamy sand soil (fine-loamy, mixed, thermic Aquic Hapludults) (Joost et al., 1986).

Root development of sericea into limed subsoils monitored using glass-front minirhizotron boxes indicated that sericea roots develop at approximately half the rate of alfalfa. Root growth rates (GR) ranged from 8.2 mm day^{-1} to 13 mm day^{-1} among the five sericea entries evaluated, while 'Apollo' alfalfa roots grew at 20.7 mm day^{-1} (Joost and Hoveland, 1986). Photosynthethetic CO_2 fixation in sericea has been documented to be about half that of alfalfa (Brown and Radcliffe, 1986). Therefore one probable explanation for the slower root GR is a lower availability of photosynthate for growth.

Root GR of sericea in acid subsoil (pH 4.7, 0.87 cmol (1/3 Al^{3+}) kg^{-1}) was reduced from 7% for 'Serala' to 39% for 'AU Lotan' compared with limed subsoil. Alfalfa root GR was reduced by 69% in unlimed compared with limed subsoil. Although alfalfa produced a greater amount of root length per unit area than sericea entries in both the limed and unlimed treatments, alfalfa roots growing in the unlimed subsoil were abnormally branched, discolored, and appeared thickened compared with normal appearing sericea lateral roots (Joost and Hoveland, 1986).

The mechanism of Al interference with root growth is believed to be associated with the binding of Al with phosphate groups in root tip DNA. This interaction results in reduced rate of DNA replication and abnormal cell division (Morimura and Matsumoto, 1978; Matsumoto and Morimura, 1980). Hematoxylin staining, which is specific for Al, of Al-treated alfalfa and sericea seedlings has indicated a high concentration of Al at the cell walls of sericea roots while Al accumulated in the nuclei of alfalfa (Joost, 1984). This indicates that sericea may be able to reduce the interaction of Al with DNA phosphate groups and allow normal cell division to occur.

This observation was further supported by X-ray microprobe analysis (EDS) used in conjunction with scanning electron microscopy (SEM). EDS mapping of Al distribution in the root-soil interface of Interstate sericea indicated a decrease in Al concentration as the interior of the root was approached. The maximum root concentrations of Al were observed in the cell walls of epidermal cells (Joost and Hoveland, 1985). Three types of physiological Al tolerance are recognized in plants; exclusion of Al from roots by precipitation in the rhizosphere,

[1] Assistant Professor, Agronomy Department, Louisiana Agricultural Experiment Sta., Louisiana State Univ. Agric. Center, Baton Rouge.

accumulation of Al in leaf tissue in an inactive form, and accumulation of Al on root cell walls (Foy, 1983). The last mechanism appears to be active in sericea lespedeza.

Aluminum tolerance is particularly important for deep-rooted perennial legumes due to the prevalence of Al-toxic subsurface horizons in highly weathered soils. Mahoney et al. (1983) surface-applied lime to an acid soil but were unable to ameliorate subsoil Al activity sufficiently to allow for alfalfa survival. Similar results were obtained in Georgia when lime was surface applied at 2240 or 4480 kg ha^{-1} and compared with an unlimed control. Below a 10-cm depth, both the 4480 kg ha^{-1} and the control plots exhibited a pH_{KCl} of 4.2 and an exchangeable Al concentration of 0.7 cmol (1/3 Al^{3+}) kg^{-1}. Sericea roots penetrated below the depth of lime incorporation, while alfalfa tap roots were killed upon reaching the unamended soil layers (Fig. 1). The inability of lime to move below the level of incorporation is a problem in perennial forage crops grown on acid soils where lime incorporation is impossible in established stands. The use of forage crops which are tolerant of subsoil acidity becomes particularly important in these situations.

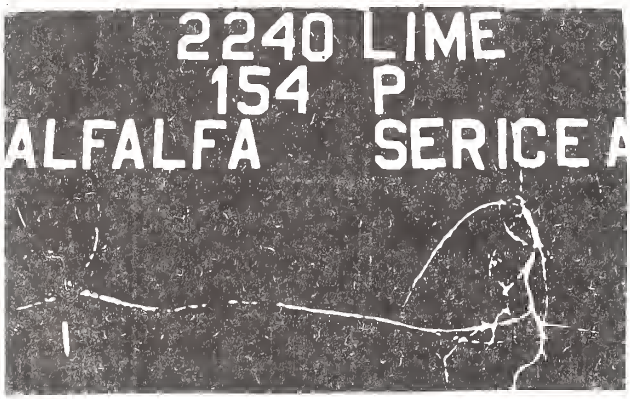

Figure 1. Comparison of Apollo alfalfa and Interstate sericea lespedeza root growth on Altavista soil receiving 2240 kg ha^{-1} lime and 154 kg ha^{-1} P, surface applied.

SERICEA RESPONSE TO PHOSPHORUS

In addition to the Al tolerance exhibited by sericea, it has also been recognized to do well under low P fertility conditions. Highly weathered soils are often P-deficient in addition to containing high levels of Al. This is probably due to the formation of insoluble crystalline Al-P compounds when P fertilizers are applied to high-Al soils (Adams, 1980). Surface application of P to a Davidson sandy clay loam (clayey, kaolinitic, thermic Rhodic Paleudult) soil in central Georgia resulted in significant increases in soil P content but did not produce a yield increase of either sericea or alfalfa over a two-year period (Table 1). Soil tests were taken from the surface 10 cm or the depth of incorporation. Both alfalfa and sericea roots grew well below the depth of incorporation. Two possible explanations exist for the lack of response to P application. Either alfalfa and sericea are capable of obtaining labile forms of P not accounted for in the Mehlich I extractant utilized or the deep root development of these two legumes allowed the plants to exploit a larger volume of soil for P. Both sericea and alfalfa reduce the pH in their rhizosphere below 4.5 which could be due to the exudation of organic acids or acid phosphatase which may aid in the dissolution of P minerals (Joost and Hoveland, 1985).

Table 1. Soil phosphorus and herbage yield in response to phosphate application, 1983-84 average.

Entry	Phosphorus Rate, kg ha^{-1} 0	34	68	102
Soil Test mmol P kg^{-1} LSD = 0.1	0.2	0.5	0.8	0.9
Yield,[1] Mg ha^{-1} LSD = NS	6.3	6.3	6.4	5.8

[1] Average of all sericea and alfalfa entries.

In a separate greenhouse experiment both sericea and alfalfa responded to P application up to 7.8 mmol kg^{-1} in pots containing 2 kg of Bradson clay loam soil (clayey, oxidic, mesic Typic Hapludult) (Table 2). Soil P levels were 0.6, 1.0, and 2.2 mmol kg^{-1}, respectively, at application rates of .65, 2.6, and 7.8 mmol P kg^{-1}. The fact that a P response was obtained in this study and not in the field study described above may be due to the small rooting volume available to the plants in the greenhouse or a difference in P forms present in the Bradson soil. Enhanced responses to P have been observed in greenhouse studies previously and attributed to P depletion in the root zone caused by matting of roots in the bottom of pots (Fox and Kamprath, 1970).

Table 2. Phosphorus response of sericea and alfalfa in acid Bradson soil.

Phosphorus rate	Yield
-mmol kg^{-1}-	- g pot^{-1} -
.65	0.6
2.60	1.8
7.80	3.3
LSD	1.2

THE POTENTIAL VALUE OF SERICEA LESPEDEZA

The adaptation of sericea to acid, infertile, high-Al soils is of great potential for the humid southeastern United States. Recent improvements in the quality of sericea have increased animal acceptability and performance. In an early cafeferia-style trial, cattle preferred fine-stemmed sericea types that were low in tannin (Donnelly, 1954). This finding led to the development of Serala, a high-yielding, high-tannin cultivar with numerous soft, pliable stems (Donnelly, 1965). Further genetic improvement at Auburn University resulted in the development of several low-tannin sericea lines that ranged in in vitro digestible dry matter (IVDDM) from 37 to 67% and the release of the low-tannin cultivar, AU Lotan (Donnelly and Anthony, 1983; Donnelly, 1981).

Both animal acceptability of the forage and animal performance are improved when low-tannin types are grazed. In a three-year Alabama grazing study comparing Serala and AU Lotan sericea with 'Cimarron' alfalfa, AU Lotan produced gains of .75 kg day^{-1} compared with .63 and .98 kg day^{-1} for Serala and Cimarron, respectively (Schmidt et al., 1986). Although steer growth on alfalfa was greater, the management problems associated with alfalfa including insect control, poor acid soil tolerance, and bloat potential, make sericea the more acceptable choice for grazing.

Part of the steer response was probably due to improved IVDDM of AU Lotan over Serala, but improved intake also could have been a factor. In a cafeteria-style trial conducted recently in Virginia, sheep consumed 80% of the available AU Lotan compared with an average of 16% of eight high-tannin entries (Wolf and Dove, 1987). Although AU Lotan is considered a "low-tannin" sericea, the forage of this cultivar still contains approximately 3 - 4 g kg^{-1} tannin. This level is sufficient to reduce insect feeding and protect animals from bloat.

AU Lotan is the first low-tannin sericea cultivar to be released; however, as mentioned above, several low-tannin lines have been identified. Problems associated with AU Lotan are low seedling vigor and low hay yields. Of the low-tannin lines that have been tested, 73-162-19, which is being considered for release, has produced consistently higher yields than AU Lotan and nearly equivalent yields to those of the high-yielding, high-tannin Serala cultivar (Table 3). Results from three environments in Georgia have shown the response of sericea to differences in temperature and soil type. Severe winter conditions prior to the third year at the Blairsville location, in the North Georgia mountains, reduced sericea stands and subsequent yield. Acid soil conditions caused a stand failure of alfalfa at the Americus location the first year of the study.

Table 3. Three-year average forage yield of sericea grown at three locations in Georgia, 1983-1985.

	Dry Forage Yield		
Entry	Blairsville	Athens	Americus
	- - - - - - - - kg ha^{-1} - - - - - - - -		
Apollo alfalfa	8990	8860	0
Serala sericea	5640	8750	8610
73-162-19 sericea	3160	8600	6810
AU Lotan sericea	2950	6920	5540
$LSD_{.05}$	1060	1150	820

The hay yield potential of improved, low-tannin sericea selections coupled with the acid, infertile soil tolerance of this legume, make it an excellent choice for the highly weathered soils of the Southeast. Although improved bermudagrass cultivars are equally adapted to this region, the cost of production for sericea is much lower due to the need for high nitrogen application rates to achieve maximum yields of bermudagrass. Although alfalfa is of higher quality and produces higher yields on limed soils, liming costs approximately $14 per hectare annually, assuming an annual application rate of approximately 1 Mg ha^{-1} required to maintain pH on most Ultisols. This surface application of lime would do nothing to alleviate subsoil acidity. In addition, several insecticide applications are normally required for successful alfalfa production. Due to the tannin concentration of sericea, insects do not normally present a problem.

Although sericea may not be the ultimate hay and pasture crop of the future, it certainly offers some potential for the 86 million hectares of highly weathered Ultisols found in the Southeast. Improvements in quality and seedling vigor will continue to improve the acceptability of sericea as a highly desirable hay and pasture crop.

Literature Cited

Adams, F. 1980. Interactions of phosphorus with other elements in soils and in plants. pp. 655-680. In E.E. Khasqwneh, E.C. Sample, and E.J. Kamprath, ed. "The Role of Phosphorus in Agriculture". Soil Sci. Soc. Am. Madison, Wisconsin.

Adams, F. 1981. Nutritional imbalances and constraints to plant growth on acid soils. J. Plant Nutr. 4:81-87.

Brown, R.H., and D.E. Radcliffe. 1986. A comparison of apparent photosynthesis in sericea lespedeza and alfalfa. Crop Sci. 26:1208-1211.

Buol, S. W. 1983. Soils of the southern states and Puerto Rico. Southern Coop. Series Bull. No. 174. 105 pp.

Donnelly, E. D. 1954. Some factors that affect palatability in sericea lespedeza, L. cuneata. Agron. J. 46:96-97.

Donnelly, E. D. 1965. Registration of 'Serala' sericea. Crop Sci. 5:605.

Donnelly, E. D. 1981. Registration of 'AU Lotan' sericea lespedeza. Crop Sci. 21:474.

Donnelly, E. D., and W. B. Anthony. 1983. Breeding low-tannin sericea. III. Variation in forage quality factors among lines. Crop Sci. 23:982-984.

Fox, R. L., and E. J. Kamprath. 1970. Phosphate sorption isotherms for evaluating the phosphate requirements of soils. Soil Sci. Soc. Am. Proc. 34:902-907.

Foy, C. D. 1983. the physiology of plant adaptation to mineral stress. Iowa St. J. Res. 57:355-399.

Haynes, R. J., and T. E. Ludecke. 1981. Yield, root morphology and chemical composition of two pasture legumes as affected by lime and phosphorus applications to an acid soil. Plant Soil 62:241-254.

Horst, W. J., A. Wagner, and H. Marshner. 1983. Effect of aluminum on root growth, cell division rate and mineral element contents in roots of Vigna unguilata genotypes. Z. Pflanzenphysiol. Bd. 109:95-103.

Joost, R. E. 1984. Aluminum tolerance and phosphorus nutrition in sericea lespedeza. 134 pp. Ph.D. Dissertation. University of Georgia. Athens, Georgia.

Joost, R. E., and C. S. Hoveland. 1985. Mechanism of aluminum tolerance in sericea lespedeza. pp. 394-396. In Proc. XV Intl. Grassl. Congr. Kyoto, Japan.

Joost, R. E., and C. S. Hoveland. 1986. Root development of sericea lespedeza and alfalfa in acid soils. Agron. J. 78:711-714.

Joost, R. E., C. S. Hoveland, E. D. Donnelly, and S. L. Fales. 1986. Screening sericea lespedeza for aluminum tolerance. Crop Sci. 26:1250-1251.

Mahoney, G. P., H. R. Jones, and J. M. Hunter. 1983. Effect of lime on lucerne in relation to soil acidity. pp. 299-302. In Proc. XIV Intl. Grassl. Congr. Lexington, Kentucky.

Matsumoto, H., and S. Morimura. 1980. Repressed template activity of chromatin of pea roots treated by aluminum. Plant Cell Physiol. 18:325-335.

Morimura, S., and H. Matsumoto. 1978. Effect of aluminum on some properties and template activity of purified pea DNA. Plant Cell Physiol. 19:429-436.

Pieters, A. J., P. R. Henson, W. E. Adams, and A. P. Barnett. 1950. Sericea and other perennial lespedezas for forage and soil conservation. USDA Circ. 863. 48 pp.

Schmidt, S. P., C. S. Hoveland, E. D. Donnelly, J. A. McGuire, and R. A. Moore. 1986. Beef steer performance on Cimarron alfalfa and Serala and AU Lotan sericea lespedeza pastures. Auburn Univ. Agric. Exp. Sta. Circ. 288.

Wolf, D. D., and D. C. Dove. 1987. Grazing preference for low tannin sericea lespedeza. pp. 216-219. In Proc. 1987 Amer. Forage and Grassl. Conf. Springfield, Illinois.

SURVIVAL, HOST SPECIFICITY, AND EFFECTIVENESS OF CLOVER RHIZOBIUM

R. W. Weaver, D. Sen, H. Schomberg, and J. Coll[1]

During recent years there has been a renewed interest in the use of legumes to produce high quality forage economically without the need for nitrogen fertilizer inputs. Most of the nitrogen is acquired through biological dinitrogen fixation in the legume root nodules. A major problem for small seeded forage legumes may be their establishment (Evers and Dorsett, 1986), particularly in nitrogen deficient soils when an effective symbiosis is not developed. Low nitrogen reserves, (Evers, 1982) and inability to compete with grasses for available mineral nitrogen (Morris and Weaver, 1987) contribute to poor establishment of small seeded legumes.

The purpose of this paper is to provide a brief description of the research that has been underway in our laboratory the past few years that relates to the nodulation and dinitrogen fixation of forage legumes grown in the Southern region. The topics to be covered include specificity of nodulation, diversity of the Rhizobium leguminosarum biovar trifolii population in the soil, survival of rhizobia on seed, sensitivity of the dinitrogen fixation process to acidic soil conditions, and the need for some mineral nitrogen during the establishment phase of small seeded legumes. For a more complete coverage of these topics the reader is referred to the excellent review article of Burton (1985).

The three most important cool season forage legumes in Texas are crimson clover (Trifolium incarnatum L.), arrowleaf clover (Trifolium vesiculosum Savi.), and subterranean clover (Trifolium subterraneum L.) (Evers and Dorsett, 1986). Arrowleaf has in the past few years become the most widely used of the three clovers, replacing crimson in many fields. Indications are that subclover will become widespread in Texas when problems with lack of hardseedness are solved. Since these three clovers are important forage resources in Texas, we conducted an experiment to determine the specificity of nineteen commercial strains of Rhizobium leguminosarum biovar trifolii on these clovers (Dixon et. al, 1984). Plants were grown under controlled conditions and inoculated with cultures of each of the rhizobial strains. All of the cultures nodulated each of the hosts. Specificity among the strains was evident with respect to their effectiveness on each host.

[1] Professor, Research Scientist, Graduate Research Assistants, respectively, Soil & Crop Sciences Dept., Texas Agricultural Experiment Station, Texas A&M Univ., College Station, TX 77843

All the strains were effective on subclover, most were effective on crimson clover but fewer than half were effective on arrowleaf clover (Table 1). Though some strains that were recommended for crimson or subclover were highly effective on arrowleaf clover, many were ineffective. We hypothesized that it would be difficult to establish arrowleaf clover in fields where crimson clover had been grown previously due to the presence of rhizobia that would be ineffective on arrowleaf. We undertook an experiment to test the hypothesis (Coll and Weaver, 1986). Soil was collected from nine fields where crimson clover was growing. Pots were filled with the soils and arrowleaf clover was seeded. To our surprise arrowleaf clover became established on eight of the nine soils when mineral deficiencies (non-nitrogenous) were alleviated. The problem with the ninth soil was not determined but it became obvious that our hypothesis was wrong.

TABLE 1. Relative effectiveness of nineteen commercial strains of Rhizobium on arrowleaf, crimson, and subterranean clover.

Clover sp.	Degree of effectiveness: Ineffective	Moderate	High
	Number of strains of Rhizobium		
Arrowleaf	6	4	9
Crimson	2	4	13
Subterranean	0	0	19

A second hypothesis was proposed to explain the results; arrowleaf clover was able to select strains that formed an effective association from the population of rhizobia present. To test the hypothesis arrowleaf clover and crimson clover were both sown on one of the soils. Rhizobium from nodules of both clovers were isolated. Eleven isolates were obtained from crimson clover and eight from arrowleaf clover which could be classified by their protein profiles as representing seven and five strains of rhizobia from each clover, respectively. All twelve of the strains were effective on crimson clover regardless of the host they were isolated from. Only three of the seven strains from crimson and only three of the five strains from arrowleaf were effective on arrowleaf. Thus from a total of nineteen nodules twelve strains of rhizobia were isolated from a single soil, with only half of these strains showing effectiveness on arrowleaf clover. The diversity of the population of rhizobia becomes very evident from these results. Populations of rhizobia in soil have been reported to be extremely diverse even though they may be closely related antigenically (Gibson et. al, 1971).

Survival of rhizobia on seed is affected by many factors including toxic factors in seed coats, susceptibility to desiccation and high temperatures. Many species of Trifolium contain water soluble substances in their seed coats that

reduce the survival of rhizobia on seed (Materon and Weaver, 1984b). The effect of these toxic substances has been demonstrated for arrowleaf clover in experiments where seeds devoid of the toxic seed coat factor were used as controls (Materon and Weaver, 1984a). Seed coat toxicity reduced survival of the rhizobia on seed by 90%. Addition of activated charcoal to the peat based inoculum or use of polyvinylpyrrolidone as the inoculant sticker greatly increased survival of rhizobia.

Use of the typical commercial inoculant adhesives containing gum arabic does not protect rhizobia against the toxic seed coat factors but they do partially protect against the influences of desiccation and high temperature (Weaver et al., 1985). The protection extends itself to the field situation (Giddens et al., 1982). Use of gum arabic as the adhesive greatly increased clover production and nodulation as compared to only using water as the adhesive (Waggoner et al., 1979). Survival of rhizobia on seed sown onto the soil surface or 1 cm into the soil was greatly enhanced by using gum arabic as the adhesive (Giddens et al., 1982). Curing of inoculants following their preparation enhances the ability of rhizobia to survive (Materon and Weaver, 1985). Delaying sowing until soil temperatures and soil moisture were suitable for germination of arrowleaf clover also greatly enhanced nodulation (Rich et al., 1983).

The pH of the soil affects the ability of arrowleaf clover to fix dinitrogen and is dependent on the strain of Rhizobium that nodulates it. Growth of plants provided with mineral nitrogen is not affected to the same extent by soil pH as those dependent on dinitrogen fixation (Table 2).

TABLE 2. Effect of soil pH on the dry weight of arrowleaf clover inoculated with different strains of rhizobia and grown for 52 days.

Strain	pH		
	5.0	5.6	6.8
		mg plant^{-1}	
Uninoc.	46*	54	90
A	72	115	202
B	84	108	151
C	35	63	153
Uninoc+N	240	257	313

*$LSD_{0.05}$ = 22

Starter mineral nitrogen greatly enhances seedling development (Table 3) and increases dinitrogen fixation (Schomberg and Weaver, 1986). In the field situation the soil provides some nitrogen through mineralization of organic matter. The need for starter nitrogen in seedling establishment must be determined for each soil and legume species.

TABLE 3. Interaction of starter nitrate nitrogen and strains of Rhizobium on dry weight of arrowleaf clover plants grown in growth pouches for 30 days.

Strains	Starter Nitrogen	
	0	0.5 mg plant^{-1}
	mg plant^{-1}	
A	10*	24
B	16	22
C	26	27
Uninoculated	5	13

*$LSD_{0.05}$ = 7.5

To determine the response of arrowleaf clover to starter nitrogen in field soil, we collected cores of soil in cans avoiding disturbance of soil structure that would enhance mineralization of soil nitrogen. Arrowleaf clover plants were grown on the soil cores with or without added nitrogen. Addition of the equivalent of 20 kg ha^{-1} mineral nitrogen provided as nitrate stimulated clover growth (Table 4).

TABLE 4. Influence of starter nitrate nitrogen on dry weight of seven arrowleaf clover plants grown on undisturbed soil cores for 30 days.

Soil	Starter Nitrogen	
	0	14 mg core^{-1}
	mg core^{-1}	
1	125	180
2	152	200
3	145	350*
4	236	425*

*Significant difference between N-levels at 0.05.

Our results suggest some management practices that will help in establishment of clover. The seed should be inoculated and planted within a few hours after inoculation. The timing of planting should correspond to soil temperatures suitable for seed germination. When soil temperatures are high germination may be delayed (Evers, 1980) causing rhizobial populations to decline rapidly under the harsh conditions of temperature and moisture stress. A commercial adhesive should be used to adhere the rhizobia to the seed and provide some protection from harsh moisture and temperature conditions. If the soil is devoid of mineral nitrogen and weed competition is not a problem it may be beneficial to provide some mineral nitrogen at rates of approximately 25 kg ha^{-1} to aid in development of seedlings while an effective symbiosis becomes established.

REFERENCES

Burton, J. C. 1985. Rhizobium relationships. pp. 161-184. In N. L. Taylor (ed.) Clover Science and Technology. Agron. Monograph 25.

Coll, J. J. and R. W. Weaver. 1986. Influence of soil populations of crimson clover rhizobia on seedling establishment of arrowleaf clover. Agron. Abstracts. p. 108.

Dixon, C. R., R. W. Weaver, and G. R. Smith. 1984. Effectiveness of rhizobial strains on arrowleaf, crimson, and subterranean clovers. Agron. Abstracts. p. 185.

Evers, G. W. 1982. Seedling growth and nodulation of arrowleaf, crimson, and subterranean clovers. Agron. J. 74:629-632.

Evers, G. W. and D. J. Dorsett. 1986. Estimated forage legume acreage and management problems in Texas. Texas Agric. Expt. Sta. Misc. Pub. 1618. 24 p.

Gibson, A. H., W. F. Dudman, R. W. Weaver, J. C. Horton, and I. C. Anderson. 1971. Variation within serogroup 123 of Rhizobium japonicum. Plant Soil Special Volume. p. 33-37.

Giddens, J. E., E. P. Dunigan, and R. W. Weaver. 1982. Legume inoculation in the Southeastern U.S.A. Southern Cooperative Series Bulletin 283.

Materon, L. A. and R. W. Weaver. 1984a. Survival of Rhizobium trifolii on toxic and non-toxic arrowleaf clover seeds. Soil Biol. Biochem. 16:533-535.

Materon, L. A. and R. W. Weaver. 1984b. Toxicity of arrowleaf clover seed to Rhizobium trifolii. Agron. J. 76:471-473.

Materon, L. A. and R. W. Weaver. 1985. Inoculant maturity influences survival of rhizobia on seed. Appl. Environ. Microbiol. 49:465-467.

Morris, D. R. and R. W. Weaver. 1987. Competition for ^{15}N depleted ammonium nitrate and N_2 fixation in arrowleaf clover-gulf ryegrass mixtures. Soil Science Soc. Amer. J. 51:115-119.

Rich, P. A., E. C. Holt, and R. W. Weaver. 1983. Establishment and nodulation of arrowleaf clover. Agron. J. 75:83-86.

Schomberg, H. and R. W. Weaver. 1986. Starter nitrogen enhances early growth of arrowleaf clover. Agron. Abstracts. p. 122

Waggoner, J. A., G. W. Evers, and R. W. Weaver. 1979. Adhesive increases inoculation efficiency in white clover. Agron. J. 71:373-377.

Weaver, R. W., L. A. Materon, M. E. Krautmann, and F. M. Rouquette. 1985. Survival of Rhizobium trifolii in soil following inoculation of arrowleaf clover. Mircen J. Appl. Microb. Biotechnology 1:311-318.

GROWTH OF SUBTERRANEAN CLOVER AS INFLUENCED BY SOIL SOLUTION COMPOSITION

Sara F. Wright and Robert J. Wright[1]

INTRODUCTION

Forage production is a major land use on many small farms in the Appalachian region (Anonymous, 1979). Perennial legumes which are long-lived, deep-rooted and persistent under a variety of stresses need to be introduced into Appalachian pastures to minimize fertilizer inputs and reduce establishment costs. Legume establishment in the Appalachian region is complicated by the shallow soils and chemical and physical limitations in the root zone. Potential Al and Mn toxicities as well as Ca deficiencies exist in a large number of soils in the Appalachian region (Wright et al., 1984). Legume production on soils with multiple toxicities and deficiencies requires selection of appropriate plant species and inoculation with effective, efficient, competitive rhizobia. Economic and topographic considerations may limit and/or preclude liming of soils and necessitate the use of acid tolerant rhizobia and legumes. Selection of legumes and rhizobia for these acid soil conditions depends upon a knowledge of the influence of soil and soil solution properties on legume growth.

Aluminum toxicity studies have generally been carried out in nutrient solution (Carvalho et al., 1981; Murphy et al., 1984; Alva et al., 1986). Limitations to root elongation have been related to concentrations and activities of Al species in nutrient solution (Alva et al., 1986). Total Al concentrations >25 uM delay nodulation, reduce the percentage of plants which nodulate, and reduce the number and dry weight of nodules produced (Murphy et al., 1984). In the current series of studies major soils of the Appalachian region, rather than nutrient solutions, were used as the growth media. Legume growth, functioning of the biological nitrogen fixation (BNF) system, and competition between introduced and naturalized strains of _Rhizobium trifolii_ were related to soil properties and soil solution composition.

Aluminum in soil solution exists in a variety of forms, only some of which are toxic to plants. Organically complexed and polynuclear forms of Al are thought to have little, if any phytotoxicity (Hue et al., 1986). The Al^{3+}, $Al(OH)^{2+}$, and $Al(OH)_2^{+}$ monomers have generally been regarded as the toxic forms of Al in aqueous systems (Alva et al., 1986; Hue et al., 1986). The objective of this series of experiments was to relate Concentrations and activities of free ions and complexes in soil solution along with soil properties to legume growth, functioning of the BNF system, and nodule occupancy by a specific _Rhizobium_ strain.

MATERIALS AND METHODS

Limed and unlimed treatments of surface and subsoil horizons from major Appalachian hill land soils were used in the experiments. Dolomitic lime was added at a rate of 2X the amount of exchangeable Al. The soils received blanket fertilizer applications of P, K, S, and micronutrients (Wright et al., 1987). Nitrogen was added in selected treatments of some of the experiments.

Subterranean clover (_Trifolium subterraneum_ L.) was chosen as the test plant because it is tolerant of a variety of soil conditions and because it is self-pollinating, and therefore genetically more stable than a cross-pollinated species. Swithchgrass (_Panicum virgatum_ L.) was also used in the experiments which related soil and soil solution properties to root and shoot growth.

Rhizobium trifolii strain 162X95 (Nitragin Co., Milwaukee, WI) was used as the inoculum to determine the response of the BNF system to acid soil factors and for competition studies. A monoclonal antibody against this strain was used to determine nodule occupancy by the enzyme-linked immunosorbent assay (ELISA) (Wright et al., 1986).

All experiments were conducted in a greenhouse under natural light with an average day temperature of 25°C and a night temperature of 20°C. Pots were watered daily to bring the soil moisture to a level corresponding to 33 kPa tension. Growth periods for the individual experiments ranged from 5 to 10 weeks. At harvest various measurements were made, depending upon the experiment. Plant growth parameters measured were shoot and root dry weight along with root length (Tennant, 1975) for one experiment.

---

[1]Research Soil Microbiologist and Research Soil Chemist, U.S. Department of Agriculture, Agricultural Research Service, Appalachian Soil and Water Conservation Research Laboratory, Beckley, WV.

Soil solutions were removed by immiscible displacement (Kinnlburgh and Miles, 1983) or centrifugation (Reynolds, 1984). Total soil solution concentrations of K, Ca, Mg, Na, Al, Mn, P, Cu, Zn and Fe were determined with ICP emission spectroscopy. Ion chromatography was used to determine SO_4^{2-}, NO_3^-, F^-, and Cl^- concentrations in soil solutions. A 15 sec reaction with 8-hydroxyquinoline (James et al., 1983) was used to estimate toxic Al in soil solution. A modified version of the GEOCHEM computer program (Sposito and Mattigod, 1980) containing equilibrium constants from Lindsay (1979) was used to calculate concentrations and activities of free ions and complexes in soil solution. Statistical Analysis System (SAS) programs were used to relate soil and soil solution properties to growth, functioning of the BNF system, and nodule occupancy.

RESULTS AND DISCUSSION

Shoot and root growth of subterranean clover and switchgrass in limed and unlimed treatments of 10 acidic subsoil horizons from the Appalachian region are shown in Fig. 1. Growth index values in Fig. 1 were calculated from the relationship: GI = (growth without lime/growth with lime) x 100. Low GI values in several of the soil horizons indicated very poor growth in unlimed treatments of these soils. Switchgrass growth was less sensitive to soil acidity than that of subterranean clover. This is reflected in the generally higher GI values for switchgrass over all three growth parameters. Switchgrass root length, in particular, was far less sensitive to unlimed soil conditions than that of subterranean clover.

Activities of Al^{3+} ($a_{Al^{3+}}$) in the soil solutions of unlimed soil horizons were calculated using the GEOCHEM program. Plots of switchgrass and subterranean clover root length GI as a function of $a_{Al^{3+}}$ are shown in Fig. 2. Switchgrass root length was much less sensitive to $a_{Al^{3+}}$ than subterranean clover root length. Activities of 9.3 and 45.5 umAl^{3+} were associated with a 50% reduction in root length for subterranean clover and switchgrass, respectively.

Several investigators have demonstrated in nutrient culture experiments that Ca and other cations, as well as pH influence the expression of Al toxicity (Alva et al., 1986; Kinraide and Parker, 1987). Multiple regression equations were developed to relate subterranean

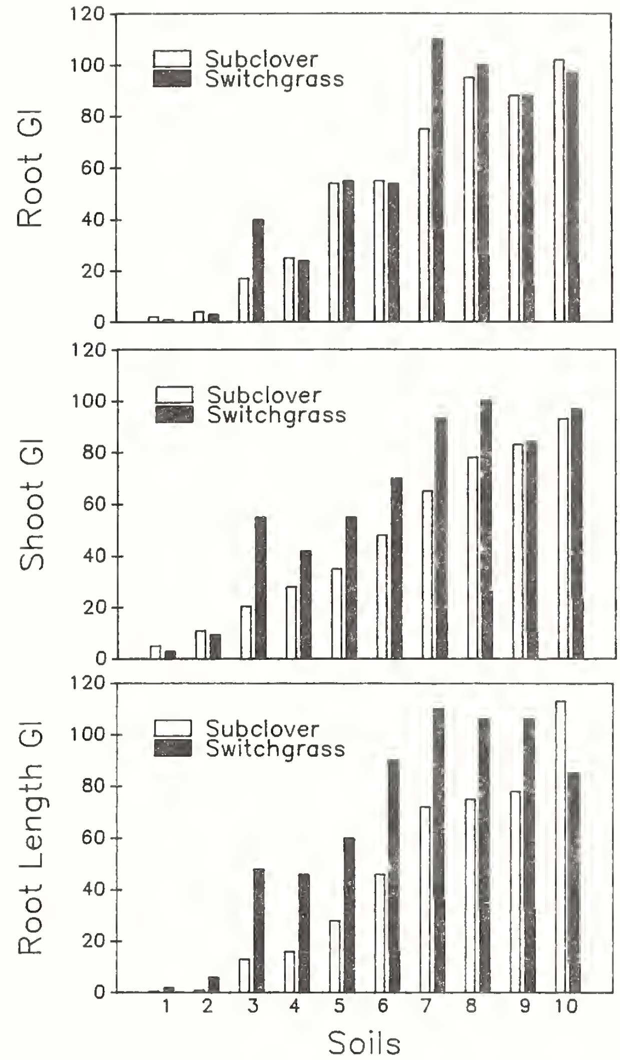

Fig. 1. Growth index values [(growth without lime/growth with lime) x 100] for roots and shoots of subterranean clover and switchgrass in 10 surface soils from the Appalachian region.

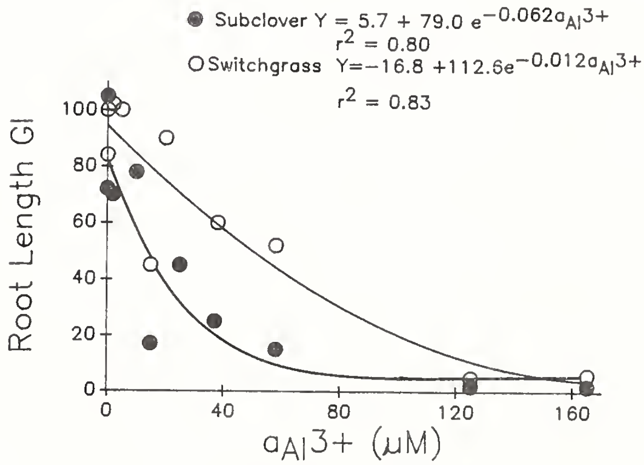

Fig. 2. Switchgrass and subterranean clover root length growth index as a function of Al^{3+} activity.

clover and switchgrass growth parameters to $a_{Al}3+$, $a_{Ca}2+$, $a_{Mg}2+$, soil solution pH and interaction terms containing Ca and Al. Inclusion of soil solution pH, $a_{Ca}2+$ and $a_{Ca}2+/a_{Al}3+$ with $a_{Al}3+$ significantly increased the predictive ability of the regression equations for subterranean clover. Improvements in R^2 were not as dramatic for switchgrass root growth, suggesting its lower sensitivity to soil solution pH and $a_{Ca}2+$ in this experiment. An equation of the form: Root length GI = 905.2 $-104.8e^{-0.049aAl^{3+}}$ + 219.6 soil solution pH (R^2 = 0.945) best described subterranean clover root length. These findings confirm the conclusion that soil solution pH needs to be included along with Al and measures of soil or soil solution Ca when considering Al phytotoxicity relationships.

Effects of soil chemical properties on the symbiosis between subterranean clover and R. trifolii strain 162X95 were studied in the top 15 cm of 13 soils (Wright et al., 1987). Relative dry matter production of inoculated/+N treatments was used to determine the response of the BNF system to soil conditions (Fig. 3). Three groups of soils were indicated: complete inhibition of BNF, limited BNF and unlimited BNF. Mean soil and soil solution properties for the groups are given in Table 1. There was some overlap of values for properties associated with individual soils, but trends are indicated by these means. Using easily measurable soil chemical properties, the following equation related relative dry matter production to pH and soil Al saturation: Inoculated/+N x 100 = -140 + 46.83 (soil solution pH) - 0.31 (Al concentration x 100/CEC) (r^2 = 0.66).

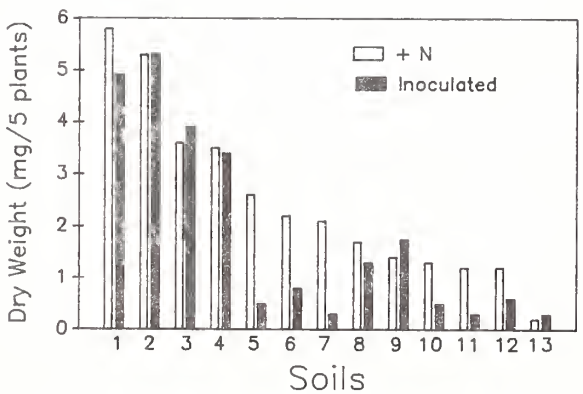

Fig. 3. Relative dry matter production of inoculated/+N treatments of subterranean clover in 13 surface soils of the Appalachian region.

BNF	Soil pH	Soil Al sat %	Soil Ca sat %	Soil Solution $a_{Al}3+$ µM	Soil Solution $a_{Ca}2+$ µM
none (3)	4.24	75.0	10.2	29.4	497
limited (5)	4.49	66.4	11.7	9.8	344
unlimited (5)	5.38	16.6	54.0	0.1	1520

Table 1. Mean values of soil and soil solution properties and the response of subterranean clover N_2-fixation in 13 surface soils from the Appalachian region. The number in parenthesis is the number of soils in the group.

The influence of soil properties on competition between an introduced R. trifolii strain and a naturalized strain (WV 22) was studied in limed and unlimed portion of 10 subsoil horizons. A 1:1 mixture of strains was inoculated in liquid form on germinating subclover. Soil and soil solution chemical properties were correlated with nodule occupancy by the introduced strain. Significant ($P < 0.05$) simple correlations between percent nodule occupancy by the introduced strain and soil properties were obtained for soil pH (1:1 H_2O), soil solution pH, Al saturation, exchangeable Al, log $a_{Ca}3+/a_{Al}3+$, and soil solution summation of mononuclear Al activity (Al^{3+} + hydroxy-Al species). Soil pH gave the best linear estimate of nodule occupancy by strain 162X95 (Fig. 5), but the regression accounted for only half of the variability of the response. Nodule occupancy was related to pH, Al and Ca by the equation : % nodule occupancy = -67.8 + 31.3 soil pH - 1.7 $a_{Al}3+$ -13.3 log $a_{Ca}2+/a_{Al}3+$ (R^2 = 0.74) indicating that several soil acidity factors are involved in nodule occupancy.

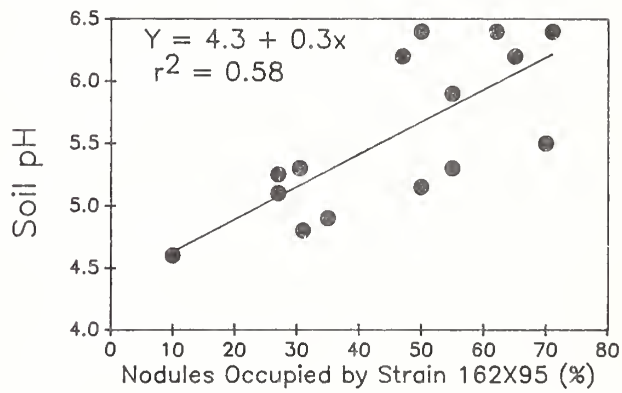

Fig. 4. Nodule occupancy by R. trifolii strain 162X95 in 1:1 competition with a naturalized strain as a function of pH. Limed or unlimed treatments of subsoils from the Appalachian region were used as the test media.

In these investigations soil and soil solution properties were related to

legume growth, functioning of the BNF system and nodule occupancy. These studies demonstrated that several soil factors including pH, Ca and Al control the expression of Al toxicity. A knowledge of the speciation of toxic and nutrient elements in soil solution allows the identification of soils which require the selection of tolerant legumes and rhizobia.

REFERENCES

Alva, A. K., D. G. Edwards, C. J. Asher, and F. P. C. Blamey. 1986. Effects of phosphorus/aluminum molar ratio and calcium concentration on plant response to aluminum toxicity. Soil Sci. Soc. Am. J. 50:133-137.

Anonymous. 1979. Appalachia. A Reference Book. 2nd edition. Appalachian Regional Commission, Washington, D.C.

Carvalho, M. M., D. G. Edwards, C. S. Andrew, and C. J. Asher. 1981. Aluminum toxicity, nodulation and growth of Stylosanthes species. Agro. J. 73:261-265.

Hue, N. V., G. R. Craddock, and F. Adams. 1986. Effect of organic acids on aluminum toxicity in subsoils. Soil Sci. Soc. Am. J. 50:28-34.

James, B. R., C. J. Clark and S. J. Riha. 1983. An 8-hydroxyquinoline method for labile and total aluminum in soil extracts. Soil Sci. Soc. Am. J. 47:893-897.

Kinnlburgh, D. G. and D. L. Miles. 1983. Extraction and chemical analysis of interstitial water from soils and rock. Environ. Sci. Technol. 17:362-368.

Kinraide, T. B. and D. R. Parker. 1987. Cation amelioration of aluminum toxicity in wheat. Plant Physiol. 83:546-551.

Lindsay, W. L. 1979. Chemical Equilibria in Soils. John Wiley, NY.

Murphy, H. E., D. G. Edwards and C. J. Asher. 1984. Effects of aluminum on nodulation and early growth of four tropical pasture legumes. Aust. J. Agric. Res. 35:663-673.

Reynolds, B., 1984. A simple method for the extraction of soil solution by high speed centrifugation. Plant Soil 78:437-440.

Sposito, G. and S. V. Mattigod. 1980. GEOCHEM: A computer program for the calculation of chemical equilibria in soil solution and other natural water systems. Kearney Foundation of Soil Science, University of California, Riverside.

Tennant, D. 1975. A test of a modified line intersect method for estimating root length. J. Ecol. 63:995-1001.

Wright, R. J., V. C. Baligar, J. L. Hern and O. L. Bennett. 1984. Acidity related limitations to plant growth in Appalachian soils. Agro. Abstracts p. 225.

Wright, S. F., J. G. Foster and O. L. Bennett. 1986. Production and use of monoclonal antibodies for identification of strains of Rhizobium trifolii. Appl. Environ. Microbiol. 52:119-123.

Wright, S. F., R. J. Wright and O. L. Bennett. 1987. Comparative growth responses of N_2 fixing and N-fertilized subterranean clover on acid soils. Plant Soil 97:151-154.

INFLUENCE OF FORAGE LEGUMES ON GROWTH OF DEER

Mark K. Johnson[1]

Generally, wildlife professionals have considered supplemental feeding of wildlife unjustifiable based on costs vs returns. However, this philosophy has been recently challenged based on perceived demand for hunting opportunities (Ozoga and Verme 1982). Furthermore, many hunting clubs plant significant acreages of food plots for white-tailed deer (Odocoileus virginianus) and most of these food plots are planted without knowledge as to whether wildlife actually benefit. Some farmer's cooperatives in Louisiana have reported that about 75% of seed and fertilizer that they sell is for use by hunting clubs.

A large body of publications suggests that native range provided by more than 200 million acres of upland forests in the Southeast fails to provide high enough quality forage for maximum growth of deer. At Louisiana State University, we are attempting to identify forage crops that have the greatest potential for improving production, growth and antler development of deer, and hunter success. Our emphasis has been primarily toward use of forage legumes to reduce management costs for replanting and fertilization compared to that needed for forage grasses. Originally, our research was designed to improve range for cattle. However, cattlemen in Louisiana were more interested in deer use of our research plots than cattle use. Therefore, we were gradually pressured to concentrate our efforts on responses of deer to different forage programs. Our continuing approach is to identify forages with the best potential for growing deer using captive animals, testing responses of free-ranging deer to food plots and comparing deer use of food plots vs pastures for cattle having the same forage crops. Presently, some deer hunting clubs that do not have open land for planting are negotiating cost-sharing of pastures with landowners if they will modify their cattle forage programs.

METHODS

Cool-Season Forages

Fourteen 0.5-acre food plots were established in fall 1983 with subterranean clover (Trifolium subterraneam) (7 plots) or gulf ryegrass (Lolium multiflorum) (7 plots). Plots were distributed over 3000 acres of upland mixed pine-hardwood forest interspersed with native pastures (about 15% of the area) where the plots were planted and fenced to exclude cattle grazing. The study area was about 5 km south of Clinton, LA in East Feliciana Parish. Plots were maintained each fall for 3 years. The area contained a population of about 75 deer. Each winter yearling bucks from the study area and from another area of similar habitat without food plots were harvested and weighed. Diet analysis was performed to determine proportions of the deer's diet made up by the forages. Specific procedures are available elsewhere (Delany 1985).

During winter 1984-85 and 1985-86, grazing trials were performed with captive, weaned fawns to compare weight gains on subterranean clover, gulf ryegrass, wheat (Triticum aestivum) and oats (Avena sativa).

Warm Season Forages

From 1982 through 1984, a variety of warm season forages were field tested to determine their utility for deer food plots. Included in these tests were sunflowers (Helianthus spp.), soybeans (Glycine spp.), cowpeas (Vigna sinensis), teosinte (Zea mexicana) and American jointvetch (Aeschynomene americana). Only American jointvetch was used heavily, continuously, and withstood the heavy unregulated grazing pressure from wild deer.

During summer 1985 and 1986, the 14 food plots were planted with American jointvetch and deer sampled as before. During summer 1986, 30 captive yearling deer were used in replicated grazing trials (N = 2 paddocks) to compare growth of deer using this forage free-choice plus bagged feed free-choice to growth of deer that only had a bagged feed formulated to simulate the quality of diets obtained by deer from native forage. Data reported here are means ± standard errors.

RESULTS

Cool-Season Forages

During the study, nearly all wild deer used the food plots and subterranean clover made up more than twice as much of the deer diet (25.3 ± 1.5%) as ryegrass (12.6 ± 0.9%). Deer use of subterranean clover significantly improved the quality of diet obtained by wild deer (Johnson et al. 1987). After 3 years of a food plot program, weights of yearling bucks increased from about 96 ± 8 lbs to 113 ± 4 lbs while weights of deer from the area without food plots did not increase 99 ± 6 lbs vs 96 ± 3 lbs.

Johnson et al. (1985) demonstrated that weaned fawns grazing for 143 days gained about twice as

[1] School of Forestry, Wildlife, and Fisheries, Louisiana Agricultural Experiment Station, LSU Agricultural Center, Louisiana State University, Baton Rouge, LA 70803. Approved for publication by the Director of the Louisiana Agricultural Experiment Station as manuscript number 87-22-1134.

much weight on subterranean clover as they did on ryegrass. Similar results were obtained when the study was repeated a second year (Johnson et al. 1987). In addition, wheat produced as much gain as subterranean clover, gains produced by oats were intermediate between those produced by ryegrass vs subterranean clover, and gains produced by a simulated native diet were similar to those produced by ryegrass. Therefore, some forages used for food plots or for cattle pastures can have a significant influence over growth of deer. These results are particularly significant because most hunting clubs plant ryegrass which does not appear to improve performance of deer. Results supporting this conclusion were obtained when a herd of deer in St. Charles Parish, La. was supplemented with 100 acres of ryegrass for 2 years. Initially, average weights of yearling and older bucks were 89 $\pm$ 5 and 119 $\pm$ 5 lbs, respectively. After use of the 100 acres of ryegrass, which was heavily used by the deer, weights failed to increase (90 $\pm$ 3 and 116 $\pm$ 5 lbs, respectively). These results provide convincing evidence that ryegrass does not improve the quality of deer diets compared to that obtained from native forages.

Warm-Season Forages

American jointvetch produced an average of 5,081 $\pm$ 333 lbs of oven dry forage per acre/yr over 2 growing seasons (Keegan and Johnson 1987). Removal of forage from the plots by deer averaged 2,996 $\pm$ 371 lbs per acre/yr. We estimated that each wild deer obtained about 1.2 lbs of oven-dry forage per day from July through October. The amount of crude protein in parts of American jointvetch consumed by deer ranged from 22.3 to 33.9%. Following 2 years of grazing American jointvetch in summer and subterranean clover in winter, body weights of yearling bucks increased further to 120 $\pm$ 4 lbs. Body weights of yearling bucks from the area without food plots remained the same 95 $\pm$ 3 lbs. Furthermore, antler development of bucks in this age class was also significantly improved 5.4 $\pm$ 0.9 oz (4.4 points) 2.4 $\pm$ 0.3 oz (2.4 points), respectively. Body weights of older bucks were also significantly greater (153 $\pm$ 8 lbs vs 128 $\pm$ 7 lbs, respectively).

In October, captive yearling bucks that had had subterranean clover or wheat in winter plus American jointvetch in summer averaged 142 $\pm$ 5 lbs while the same age bucks maintained on a simulated native diet averaged 115 $\pm$ 6 lbs (Schultz and Johnson 1987). Antlers of yearling bucks were also larger (6.6 $\pm$ 1.5 oz; 6 $\pm$ 1 points vs 3.5 $\pm$ 1.1 oz; 4 $\pm$ 1 points, respectively). Presently, we are not able to distinguish between the amount of improvement that can be attributed to deer grazing American jointvetch compared to the improvement attributed to use of subterranean clover in winter. Further study is needed to properly quantify the effects of American jointvetch on performance of deer.

LITERATURE CITED

Delany, B. W. 1985. Effects of cool-season food plots on white-tailed deer. Unpublished M.S. Thesis, Louisiana State Univ., Baton Rouge. 46 pp.

Johnson, M. K., S. P. Lynch, and J. A. Zeno. 1985. Effects of supplemental ryegrass versus subterranean clover on fawn growth. Proc. Annu. Conf. Southeast. Assoc. Fish and Wildl. Agencies 39:644-648.

Johnson, M. K., B. W. Delany, S. P. Lynch, J. A. Zeno, S. R. Schultz, T. W. Keegan, and B. D. Nelson. 1987b. Effects of cool-season agronomic forages on white-tailed deer. Wildl. Soc. Bull. In press.

Keegan, T. W., and M. K. Johnson. 1987. Yield, quality and white-tailed deer use of American jointvetch. Proc. 1987 Forage and Grassl. Conf., Amer. Forage and Grassl. Coun., Lexington, Ky. pp. 144-147.

Ozoga, J. J., and L. J. Verme. 1982. Physical and reproductive characteristics of a supplementally-fed white-tailed deer herd. J. Wildl. Manage. 46:281-301.

Schultz, W. R., and M. K. Johnson. 1987. Weight gain and antler development of yearling white-tailed deer on American jointvetch. Proc. 1987. Amer. Forage and Grassl. Conf., Amer. Forage and Grassl. Coun., Lexington, Ky. pp. 148-150.

APHID FLIGHT ACTIVITY RELATIVE TO INCIDENCE OF NONPERSISTENTLY TRANSMITTED VIRUSES IN ARROWLEAF AND WHITE CLOVER BAIT PLANTS

M. M. Ellsbury and M. R. McLaughlin[1]

INTRODUCTION

Clovers grown as forage in the Southeastern United States may be infected by several aphid-transmitted viruses. Among these are alfalfa mosaic virus (AMV), bean yellow mosaic virus (BYMV), clover yellow vein virus (CYVV), cucumber mosaic virus (CMV), peanut stunt virus (PSV), and red clover vein mosaic virus (RCVMV). Edwardson and Christie (1986) compiled listings of 79 aphid species reported to transmit AMV, BYMV, CMV or RCVMV. Blackman and Eastop (1984) listed 14 aphid species that commonly colonize clovers worldwide and 9 species that have been recorded less frequently from clovers. Transient aphid species that do not colonize forage legumes probably also serve as vectors of forage legume viruses.

Monitoring of aphid flight activity is an important component in epidemiological study of aphid-transmitted plant virus diseases. Many different trapping devices have been developed for monitoring aphid flight activity (Taylor and Palmer 1972). Moericke (1955), Evans and Medler (1966) and A'Brook (1968) found that placing traps against a contrasting background increased the quantity of aphids trapped. Taylor and Palmer (1972) distinguished between aphid traps that produce a true sample of aphid populations and those that exert an attractive effect on aphids or provide a measure or relative abundance of aphids trapped that is not necessarily representative of absolute aphid abundance.

Yellow water pan traps, often termed Moericke traps, and yellow sticky board traps have a disadvantage in that they attract aphids to colored surfaces and thus may produce biased samples. Also, removal of aphids from sticky traps for identification is difficult without damage to the specimens. Irwin (1980) characterized aphid traps that attract insects to colored surfaces as providing a skewed measure of aphid populations. Irwin (1980) utilized a trap that incorporated a green ceramic tile as the attractive surface. Spectral reflectance of the green tile surface closely approximated that of plant foliage so that presumably no bias due to differential attractiveness was introduced into aphid samples taken by the trap. A'Brook (1964, 1968) found that incidence of groundnut rosette virus and aphid colonies was higher in field plantings where bare soil was exposed between plants. Contrast between the green color of the plants of the bare soil was apparently a stimulus for aphid landings. Clover bait plants for viruses and green tile water-pan aphid traps placed on bare soil plots provide a sensitive relative measure of virus incidence and aphid flight activity without the bias attendant to differentially attractive colored surface commonly used in yellow water-pan aphid traps (Ellsbury 1986 unpublished data).

To increase our epidemiological knowledge of aphid-transmitted forage legume virus diseases, two studies were initiated in 1983 involving field exposure of virus bait plants against contrasting bare soil backgrounds and concurrent trapping to monitor aphid flight activity. One study was a multi-state cooperative effort among participants of Southern Regional Research Project S-127, Forage Legume Viruses. The second was a long-term study still in progress by the Forage Research Unit, U.S. Department of Agriculture, Agricultural Research Service at Mississippi State, Mississippi. The objective of both studies was to monitor incidence of virus infections among clover bait plants in relation to seasonal aphid flight activity in the vicinity of forage legume research plots.

MATERIALS AND METHODS

In the multistate study, scientists at each cooperating location followed the same general protocol as used in the long-term study at Mississippi State, described below. States represented in the study included Texas, Florida, Georgia, North Carolina, Kentucky, Louisiana, and Mississippi.

Virus Bait Plants

Seedlings of arrowleaf clover (*Trifolium vesiculosum* Savi), crimson clover (*T. incarnatum* L.) and white clover (*T. repens* L.) were grown in an insect-free greenhouse, transplanted individually to 1-gal cans and, at 6-8 weeks of age, placed in the field for 1 week. Species used in the multistate study varied among locations. Twelve plants of each species used at a given location were exposed each week. Plants were positioned with their

---

[1]USDA, Agricultural Research Service, Crop Science Research Lab., Forage Research Unit, P. O. Box 5367, Mississippi State, MS 39762

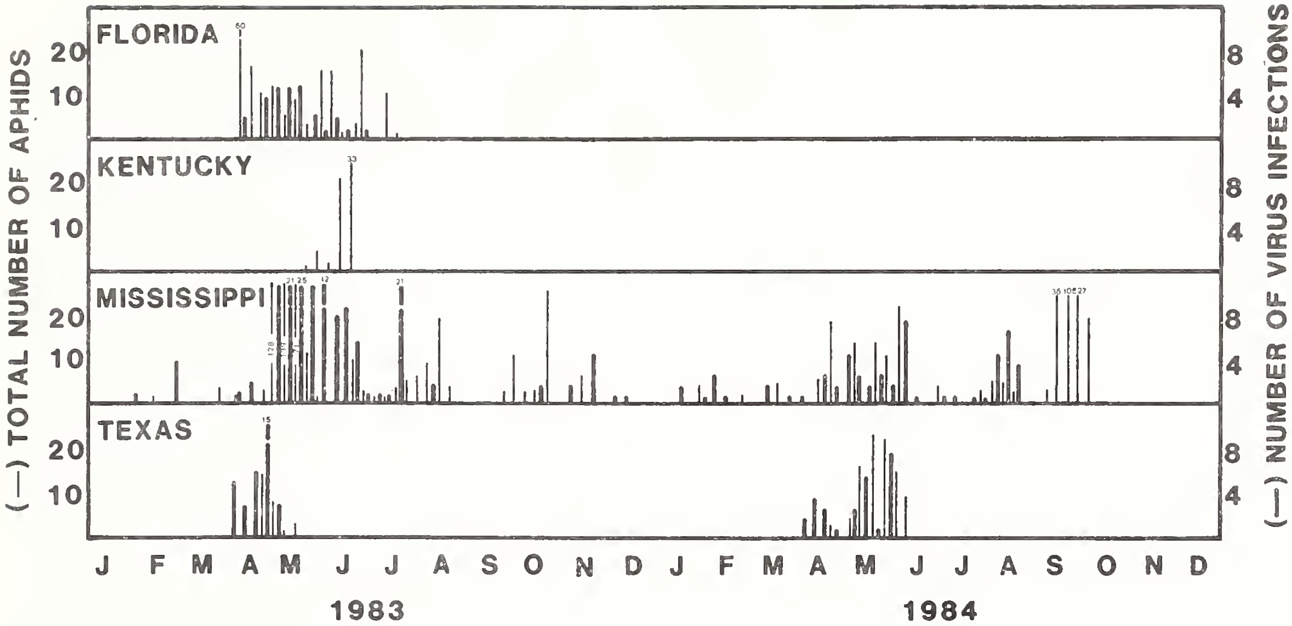

Figure 1. Weekly total aphid trap catches and virus incidence during 1983 and 1984 from arrowleaf clover bait plants in Florida, Kentucky, Mississippi, and Texas.

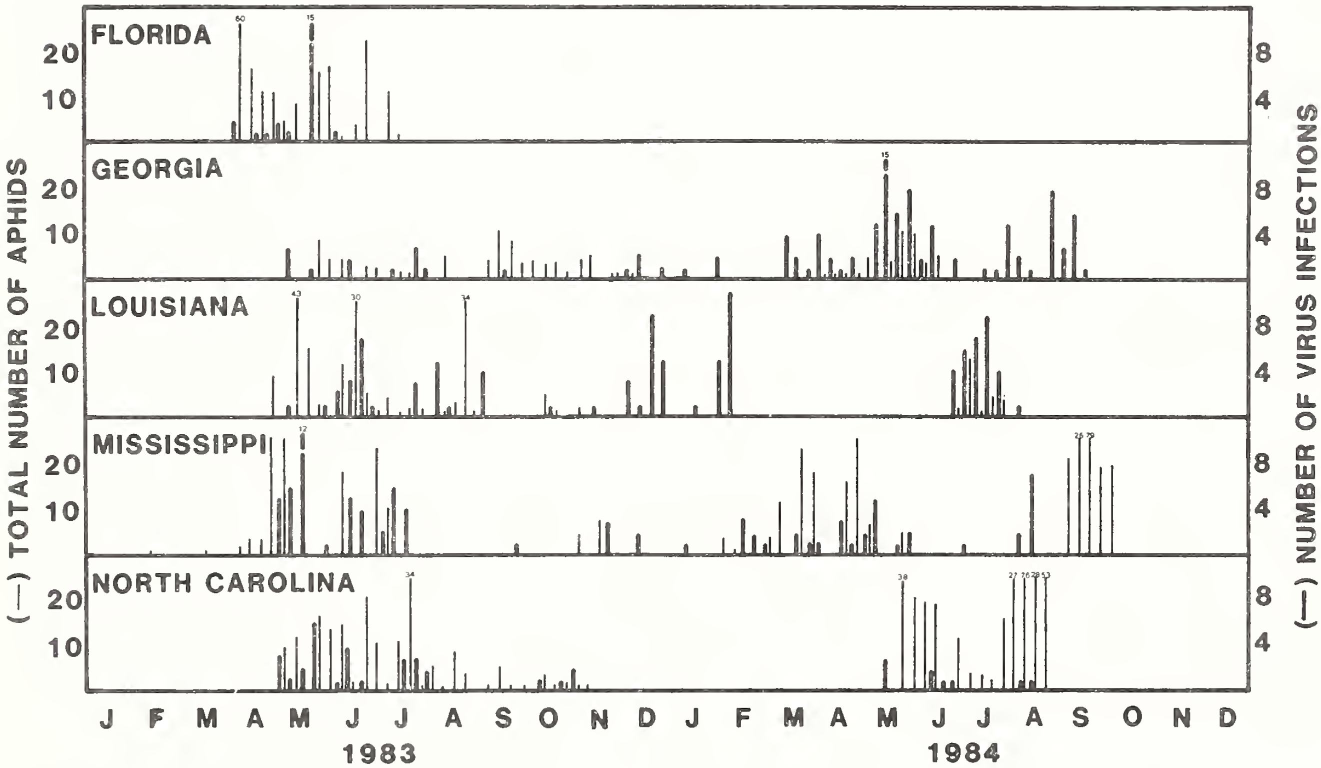

Figure 2. Weekly total aphid trap catches and virus incidence during 1983 and 1984 from white clover bait plants in Florida, Georgia, Louisiana, Mississippi, and North Carolina.

crowns at the soil line by placing their containers inside sunken metal stovepipe sleeves (15 cm diam X 20 cm deep). Plants were arranged in three groups of 4 plants for each species. Plants within each group were placed at the N, E, S, and W compass points, 1 m from a centrally located water pan aphid trap. Ground between the bait plants was kept free of vegetation in order to maximize contrast between bait plants and the soil background.

After 1 wk exposure, plants were removed from the field, sprayed with a systemic insecticide, then returned to an insect-free greenhouse. Two weeks later, samples of leaves were collected from individual field-exposed bait plants, placed between layers of moist paper towelling, labelled and stored inside sealed plastic bags at -20 C. Leaf samples were later tested for virus infections by enzyme-linked immunosorbent assay (ELISA) (McLaughlin and Barnett 1978). Tests of samples from the multistate study used ELISA plates mailed to cooperators from Mississippi State, as described in McLaughlin et al. (1984).

Aphid Trapping

Aphids were collected weekly from water pan traps containing 50% ethylene glycol. The traps were equipped with a clear plastic overflow reservoir designed to retain aphids during periods of rainfall. Aphids were preserved in 70% alcohol and returned to the laboratory for identification. Voucher specimens of aphids were prepared, mounted on slides and deposited in the Mississippi Entomological Museum, Department of Entomology, Mississippi State University.

RESULTS AND DISCUSSION

Virus disease incidence among bait plants was highest from March to June at most locations in the multistate study. Arrowleaf clover bait plant infections and associated aphid trap catches are summarized for 4 states in Fig. 1. Data from white clover for 5 states are presented in Figure 2. Both arrowleaf and white clovers were used as bait plants in Mississippi in 1983 and 1984 and Florida in 1983. Five viruses were detected by ELISA: AMV, BYMV, CYVV, PSV, and RCVMV. Multiple virus infections occurred in some of the 12 bait plants exposed each week. Virus incidence also coincided generally with peak aphid flights. Some virus infections also occurred during colder months (Oct. to Feb.) when aphid trap catches were very low. There was also year to year variation in incidence of virus infections in bait plants from Georgia 1983 < 1984), North Carolina (1983 > 1984) and Mississippi (1983 > 1984).

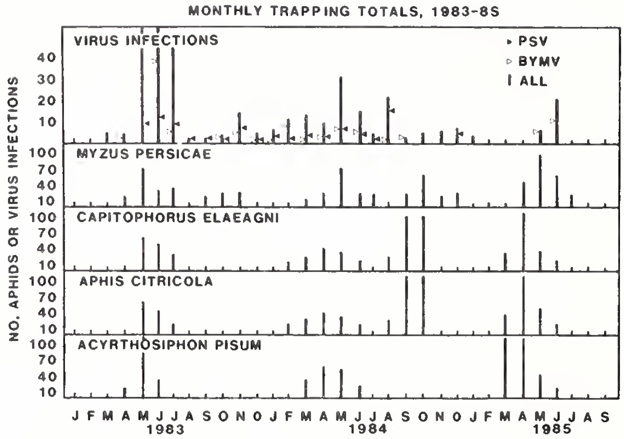

Figure 3. Monthly totals for virus incidence on arrowleaf, white and crimson clover bait plants (36 plants per week) and total aphids trapped for 4 prevalent species for which peak aphid trap catches coincided with virus incidence.

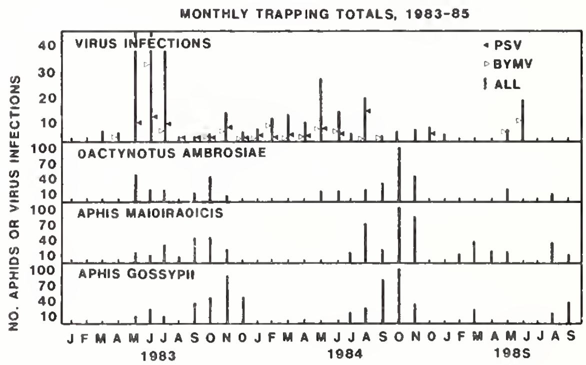

Figure 4. Monthly totals for virus incidence on arrowleaf, white and crimson clover bait plants (36 plants per week) and total aphids trapped for 3 prevalent species for which peak trap catches did not coincide well with virus incidence.

Sixty seven aphid species in 37 genera have been trapped at Mississippi State. The monthly trap totals for the most prevalent species are shown in Figures 3 and 4 for 1983 to 1985. Summarization by month of Mississippi data for virus incidence in 3 bait plant species appears at the top of Figures 3 and 4 for 1983 to 1985. Incidence of BYMV and PSV also are indicated in the portion of Figures 3 and 4 that show virus infections of bait plants. Peak trap catches of 4 aphid

species that coincided with or preceded peaks of virus incidence appear in Figure 3. These aphids, Myzus persicae (Sulzer), Capitophorus elaeagni (del Gu.), Aphis citricola van der Goot, and Acyrthosiphon pisum (Harris), are known to transmit viruses of legumes in a nonpersistent manner (Edwardson and Christie 1986). Conversely, for 3 aphid species shown in Figure 4, peak trap catches did not correspond as closely with peaks in virus incidence, and lesser numbers were trapped during periods when virus infections occurred. These species were Dactynotus ambrosiae (Thos.), Aphis maidiradicis Forbes, and A. gossypii Glover. Two of these aphids, D. ambrosiae and A. gossypii have been shown to transmit viruses that infect legumes (Edwardson and Christie 1986). Temporal separation of virus incidence and peak aphid incidence does not necessarily eliminate a particular aphid species as a potential vector. Similarly, coincidence of virus infections with peak aphid catches does not establish vector relationships. It does allow researchers to focus future studies on species which are likely candidates as vectors. However, aphids trapped less frequently may still be vectors. Seasonal live trapping of viruliferous aphids and subsequent confinement on healthy test plants to be later indexed for virus infection is needed to conclusively determine which aphid species are important vectors of forage legume viruses.

Literature Cited

A'Brook, J. 1964. The effect of planting date and spacing on the incidence of groundnut rosette disease and of the vector, Aphis craccivora Koch, at Mokwa, Northern Nigeria. Ann. appl. Biol. 54:199-208.

A'Brook, J. 1968. The effect of plant spacing on the numbers of aphids trapped over the groundnut crop. Ann. appl. Biol. 61:289-94.

Blackman, R. L. and V. F. Eastop. 1984. Aphids on the World's Crops. John Wiley. New York. 466 p.

Edwardson, J. R., R. G. Christie. 1986. Viruses Infecting Forage Legumes. Univ. of Florida. Inst. Food Agric. Sci. Monograph No. 14. 742 p.

Evans, D. A. and J. T. Medler. 1966. Improved method of using yellow-pan aphid traps. J. Econ. Entomol. 59:588-93.

Irwin, M. E. 1980. Sampling Aphids in Soybean Fields. pp. 239-59 in Sampling Methods in Soybean Entomology. M. Kogan and D. C. Herzog eds. Springer-Verlag. New York. 587 p.

McLaughlin, M. R. and O. W. Barnett. 1978. Enzyme-linked immunosorbent assay (ELISA) for detection and identification of forage legume viruses. pp. 138-145 in Proc. 35th Southern Pasture and Forage Crop Improvement Conf. June 13-14. Sarasota, FL.

McLaughlin, M. R., O. W. Barnett, P. B. Gibson and P. M. Burrows. 1984. Enzyme-linked immunosorbent assay of viruses infecting forage legumes. Phytopathology. 74:965-9.

Moericke, V. 1955. Über das Verhalten phytophager Insekten während des Befallsflugs unter dem Einfluss von Weisen Flächen. Zeit. Pflkrank. Pflpathol. Pflsch. 62:588-93.

Taylor, L. P. and J. M. P. Palmer. 1972. Aerial Sampling. pp. 189-234 in H. F. van Emden ed. Aphid Technology. Academic Press. New York. 344 p.

THE STATUS OF BERMUDAGRASS RESISTANCE TO THE FALL ARMYWORM

S. S. Quisenberry, T. Jamjanya, F. Whitford, P. Caballero, and C. M. Smith[1]

INTRODUCTION

The fall armyworm, Spodoptera frugiperda (J. E. Smith), is the most damaging insect pest of bermudagrass, Cynodon dactylon (L.) Pers., pastures in the southern United States (Leuck et al. 1968). Yield reduction and decreased forage quality can be attributed to fall armyworm feeding damage (Jamjanya 1987). Because the fall armyworm is the major economic pest of bermudagrass, researchers have recently begun evaluating bermudagrass genotypes for fall armyworm resistance (Leuck et al. 1968, Leuck and Skinner 1970, Pencoe and Martin 1982, Lynch et al, 1983, Quisenberry and Wilson 1985, Jamjanya 1987).

Objectives of our program are: (1) to determine the effect of bermudagrass varieties and strains on the development of fall armyworm, (2) to determine the chemical basis of bermudagrass resistance to fall armyworm, and (3) to characterize development of fall armyworm colonies on artificial diets and the effects of colony and artificial diet on the level of resistance observed when fall armyworm are evaluated on different grasses.

MATERIALS AND METHODS

Development and Host Suitability

Fourteen bermudagrasses ('Alicia', 'Brazos', 'Coastal', 'Grazer', 'Tifton 44', 'Tifton 78', 'Tifton 292', GA 77-26, GA 77-56, OSU LCB W-26, OSU 71 X 6-7, OSU 74 X 11-2, OSU 74 X 12-1, and #1 R12P5) were planted in metal flats (50 by 35 by 9 cm) containing potting soil and maintained in the greenhouse. Grass was cut every 4 weeks and fertilized with N-P-K fertilizer at a rate of 50 kg/ha. The leaves were excised (after 2 weeks regrowth) daily and used in laboratory feeding studies.

Fall armyworm used in this study were obtained from a laboratory colony reared on a modified pinto bean diet according to procedures described by Perkins (1979).

[1] Associate Professor, Graduate Student, Research Associate, Graduate Student, and Professor, Department of Entomology, Louisiana Agricultural Experiment Station, Louisiana State University Agricultural Center, Baton Rouge, Louisiana 70803

The colony and subsequent tests were maintained in a growth chamber at 26 ± 0.5°C, 14:10 (L:D), and > 50% RH. Excised bermudagrass leaves were placed on moistened cellulose wadding in plastic petri dishes (10 by 1.5 cm). One neonate fall armyworm larvae was placed in each dish and observed daily for development and survival. A host suitability index (HSI = pupal weight (mg)/leaf consumption (mg dry wt)/days required to complete development X percentage of survival) was calculated using the equation developed by Lynch et al. (1981).

Chemical Basis of Bermudagrass Resistance

Dried (60°C), ground (100 g per variety per trial) foliage ('Grazer', OSU 71 X 6-7, 'Coastal', or 'Tifton 292') was extracted with petroleum ether, followed by dichloromethane and methanol using the soxhlet apparatus. After methanol extraction, foliage was dried at 60°C and extracted in water for 24 h. Extracts were dissolved in petroleum ether, dichloromethane, or methanol and absorbed onto α - cellulose in a 1:1 (petroleum ether and dichloromethane) or 2:1 (methanol) ratio and force air dried at 60°C prior to incorporation into modified pinto bean diet. The water extract was added directly to the diet.

Each extract was combined with 312 ml of diet and dispensed into 29.7 ml polystyrene cups (n = 70 cups/treatment). One neonate fall armyworm larva was placed in each cup and the development and survivorship monitored.

Impact of Colony and Artificial Diet on Evaluation of Bermudagrass Resistance

Three fall armyworm colonies were used in these studies. The Louisiana (LA) colony was field collected from bermudagrass and maintained in the laboratory for 25 generations. The Georgia colony had been reared in the laboratory for 300+ generations and new genetic material had not been added to the colony during this period. The original source of the Georgia colony was a collection made in 1960 of fall armyworm larvae feeding on bermudagrass and was supplemented in 1963 from an unidentified plant source (Burton 1967, Perkins 1979). The Mississippi (MS) colony was originally collected from corn and in August 1985 (F. M. Davis personal communication). The Georgia colony was maintained in laboratory as 2 separate colonies (GA-1 and GA-2). The 2 Georgia colonies differed only in the artificial diet used to rear the larval stage. The GA-1 colony had initially been reared on

the pinto bean (PB) diet for 300+ generations and then transferred to a modified pinto bean (MPB) diet for 11 generations prior to the initiation of the study, while the GA-2 colony was reared on PB diet. The LA colony was maintained on a MPB and the MS colony on Southwestern corn borer (SWCB) diets up until the time of the study.

Neonate fall armyworm larvae from the GA-1, GA-2, LA, and MS colonies were placed individually on diet in polystyrene cups (29.7 ml) containing one of the following diets: MPB, PB, velvetbean caterpillar (VBC), or SWCB. Treatments were maintained in a growth chamber at 26.7 ± 0.5°C, 14:10 (L:D), and > 50% RH. Each treatment combination was replicated 36 times with a subsample of 2 cups. Development and survivorship was monitored on a daily basis.

Bermudagrass var. 'Coastal' and 'Tifton 292', centipedegrass (Eremochola ophiuroides [Munro]), and zoysia (Zoysiia japonica Steud.) were fed to fall armyworm larvae. 'Tifton 292' (Lynch et al. 1983), centipedegrass (Wiseman et al. 1982), and zoysia (Chang et al. 1986) were used in this study because these grasses had previously been reported as resistant to fall armyworm. The experiment was designed as a split-split plot with colony (GA-1, GA-2, LA, MS) as the whole plot, reared on a diet (MPB, PB, VBC, SWCB) as the split plot, and grass ('Tifton 292', 'Coastal', centipedegrass, zoysia) as the split-split plot for a total of 64 treatments. Each treatment was replicated 4 times with 4 subsamples (n = 16). One neonate larvae from each colony and diet combination was placed excised leaves contained in a plastic petri dish (10 by 1.5 cm) on moistened cellulose wadding.

RESULTS AND DISCUSSION

Development and Host Suitability

The host suitability index, the cumulative effect of antibiosis in plant tissue, for 6 of the 14 bermudagrasses evaluated for resistance to fall armyworm is given in Fig. 1. 'Tifton 78' was a more suitable host than all of the other grasses evaluated, while OSU 71 X 6-7 was the least suitable host. Based on the development, preference, and host suitability data, 'Tifton 78', OSU 74 X 12-1, and 'Grazer' are susceptible; #1 R12P5, 'Coastal', 'Tifton 292', OSU 74 X 11-2, 'Tifton 44', GA 77-26, GA 77-56, 'Brazos', and OSU LCB W-26 are intermediate in resistance; and OSU 71 X 6-7 and 'Alicia' are resistant to fall armyworm (Quisenberry and Wilson 1985, Jamjanya 1987).

Chemical Basis of Bermudagrass Resistance

Larvae fed the water leaf extract of 'Tifton 292' and 'Grazer' weighed more than larvae fed the control diet, while those fed the water leaf extract of OSU 71 X 6-7 and 'Coastal' weighed less (Fig. 2A). Weights of larvae fed the 'Grazer' dichloromethane leaf extract and the control were similar, while those fed the OSU 71 X 6-7 and 'Coastal' leaf extracts weighed less (Fig. 2B). Larval weights were ca. 25% ('Grazer') to more than 90% (OSU 71 X 6-7, 'Tifton 292', 'Coastal') lower when larvae were fed methanol leaf extracts (Fig. 2C). Larvae fed petroleum ether leaf extract of 'Grazer' were the only larvae to survive, and they weighed less than those fed the control diet (Fig. 2D).

Larval survival was greatest among individuals fed the water leaf extracts with only 24% mortality for larvae fed water extract of 'Coastal' (Fig. 3A). Larvae fed dichloromethane leaf extract of 'Tifton 292' had 100% mortality, followed by 87, 71, and 36% mortality for larvae fed dichloromethane extract of 'Coastal', OSU 71 X 6-7, and 'Grazer', respectively (Fig. 3B). Larvae survived on all methanol leaf extracts; however, larvae reared on methanol leaf extract of 'Grazer' had 66% mortality (Fig. 3C). Mortality was 100% for larvae fed petroleum ether leaf extract of OSU 71 X 6-7, 'Coastal', and 'Tifton 292', while mortality was only 60% for larvae fed petroleum either extract of 'Grazer' (Fig. 3D).

Impact of Colony and Artificial Diet on Evaluation of Bermudagrass Resistance

Differences in larval weights were especially pronounced on the SWCB diet (Table 1). Weights of larvae from the LA colony weighed much less than individuals from the other colonies. Larvae from the GA-2 colony weighed the most when reared on the PB diet, while individuals from the LA colony weighed the least. Comparisons of the 4 colonies reared on the MPB diet indicated that individuals from the LA colony weighed less than larvae reared on the other diets. When larvae were reared on the VBC diet, larval weights of individuals form the GA-2 colony were heavier than larvae from any other colony.

Table 1. Effect of diet on nine day larval weight of individuals from three fall armyworm colonies (Modified from Quisenberry and Whitford).

Colony	Diets SWCB	PB	MPB	VBC
GA-1	232 a	324 b	348 a	328 b
LA	88 c	215 d	205 c	192 c
MS	198 b	265 c	295 b	322 b
GA-2	262 a	386 a	362 a	397 a

Means within a column followed by the same letter are not significantly different ($P > 0.05$; least-squares means test).

Fall armyworm colony and artificial diet both had a significant impact on the biology of fall armyworm and influenced the level of resistance observed on various grasses (Quisenberry and Whitford). Fall armyworm acceptance of 'Coastal' and 'Tifton 292' depended on the interaction between colony and artificial diet.

CONCLUSIONS

Fall armyworm reared on OSU 71 X 6-7 and 'Alicia' showed adverse effects expressed as increased duration in developmental time, decreased larval and pupal weights, and low survivorship. Thus, antibiosis rather than nonpreference is believed to be the mechanism of resistance. The allelochemic activity among the bermudagrass extracts suggests that a variety of phytochemicals may have biological activity toward fall armyworm. Our data also demonstrate that conclusions obtained from fall armyworm resistance studies may be erroneous if colony and artificial diets used to rear fall armyworm are not taken into consideration.

LITERATURE CITED

Burton, R. L. 1967. Mass rearing the fall armyworm in the laboratory. U. S. Dep. Agric., Agric. Res. Ser., 33-117, 12 p.

Chang, N. T., B. R. Wiseman, R. E. Lynch, and D. H. Habeck. 1986. Growth and development of fall armyworm (Lepidoptera: Noctuidae) on selected grasses. Environ. Entomol. 15: 182-189.

Jamjanya, T. 1987. Consumption and utilization, biology, and economic injury levels of fall armyworm, Spodoptera frugiperda (J. E. Smith) on selected bermudagrasses. Ph.D. Dissertation, Louisiana State Univ., Baton Rouge, La.

Leuck, D. B. and J. L. Skinner. 1970. Resistance in bermudagrass affecting control of the fall armyworm. J. Econ. Entomol. 63: 1981-1982.

Leuck, D. B., C. M. Taliaferro, G. W. Burton, R. L. Burton, and M. C. Bowman. 1968. Resistance in bermudagrass to the fall armyworm. J. Econ. Entomol. 61: 1321-1322.

Lynch, R. E., W. D. Branch, and J. W. Garner. 1981. Resistance of Arachis species to the fall armyworm, Spodoptera frugiperda. Peanut Sci. 8: 106-109.

Lynch, R. E., W. G. Monson, B. R. Wiseman, and G. W. Burton. 1983. Bermudagrass resistance to the fall armyworm (Lepidoptera: Noctuidae). Environ. Entomol. 12: 1837-1840.

Pencoe, N. L. and P. B. Martin. 1982. Fall armyworm (Lepidoptera: Noctuidae) larval development and adult fecundity on five grass hosts. J. Econ. Entomol. 11: 720-723.

Perkins, W. D. 1979. Laboratory rearing the fall armyworm. Fla. Entomol. 62: 87-91.

Quisenberry, S. S. and H. K. Wilson. 1985. Consumption and utilization of bermudagrass by fall armyworm (Lepidoptera: Noctuidae) larvae. J. Econ. Entomol. 78: 820-824.

Quisenberry, S. S. and F. Whitford. Evaluation of bermudagrass resistance to fall armyworm (Lepidoptera: Noctuidae): Impact of colony and artificial diet. J. Econ. Entomol. (In Review).

Quisenberry, S. S., P. Caballero, and C. M. Smith. Influence of bermudagrass leaf extracts on development and survivorship of fall armyworm (Lepidoptera: Noctuidae) larvae. J. Econ. Entomol. (In Press).

Wiseman, B. R., R. C. Gufldner, and R. E. Lynch. 1982. Resistance in common centipedegrass to the fall armyworm. J. Econ. Entomol. 75: 245-247.

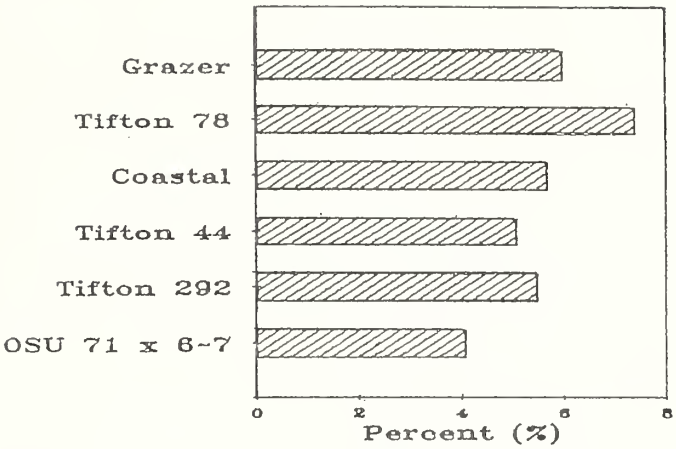

Figure 1.
Host suitability index of bermudagrasses fed to fall armyworm (modified from Jamjanya 1987).

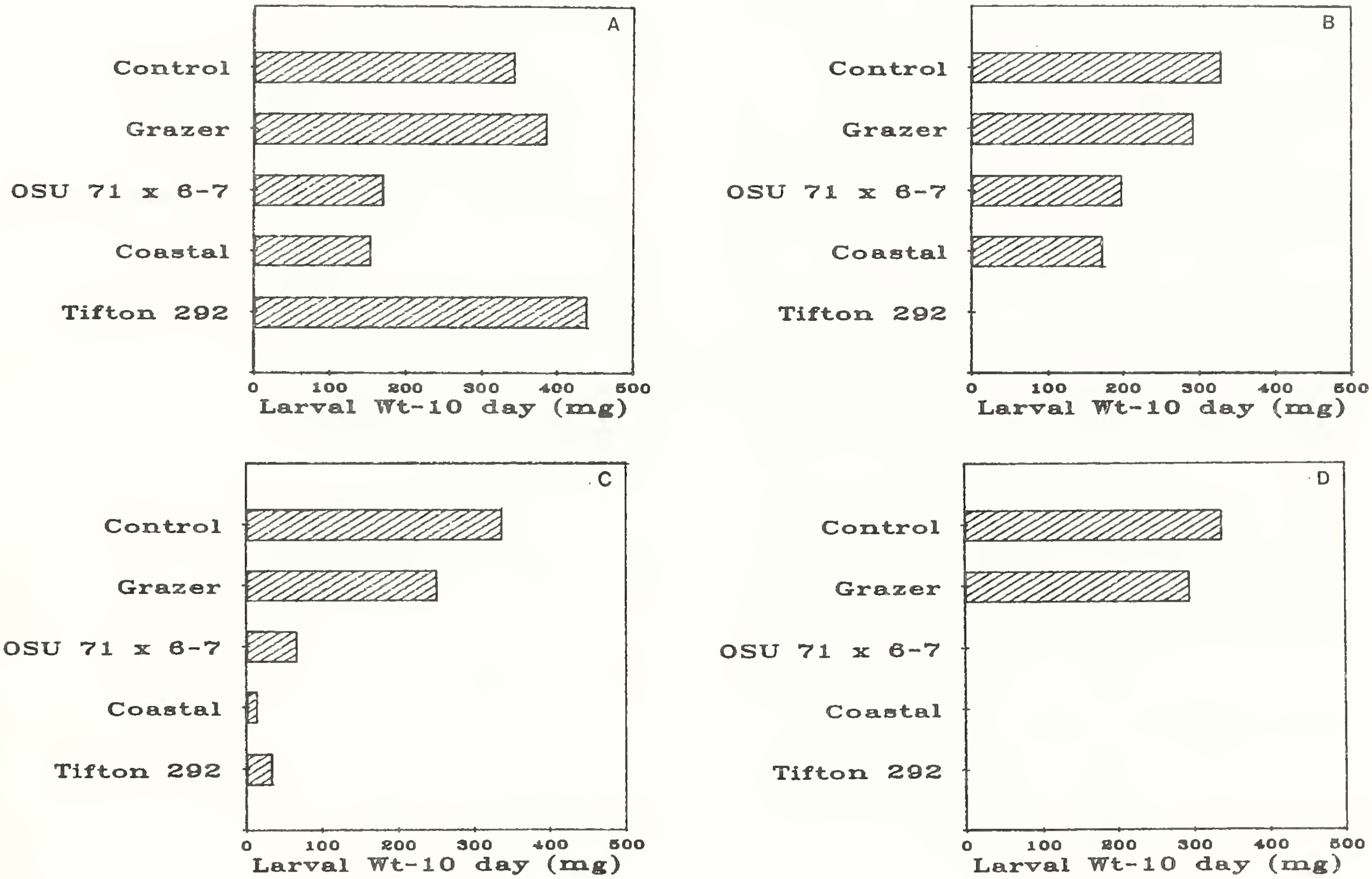

Figure 2.
Weights of fall armyworm larvae fed artificial diet supplemented with A) water, B) dichloromethane, C) methanol, and D) petroleum ether leaf extracts of bermudagrass (modified from Quisenberry et al. 1987).

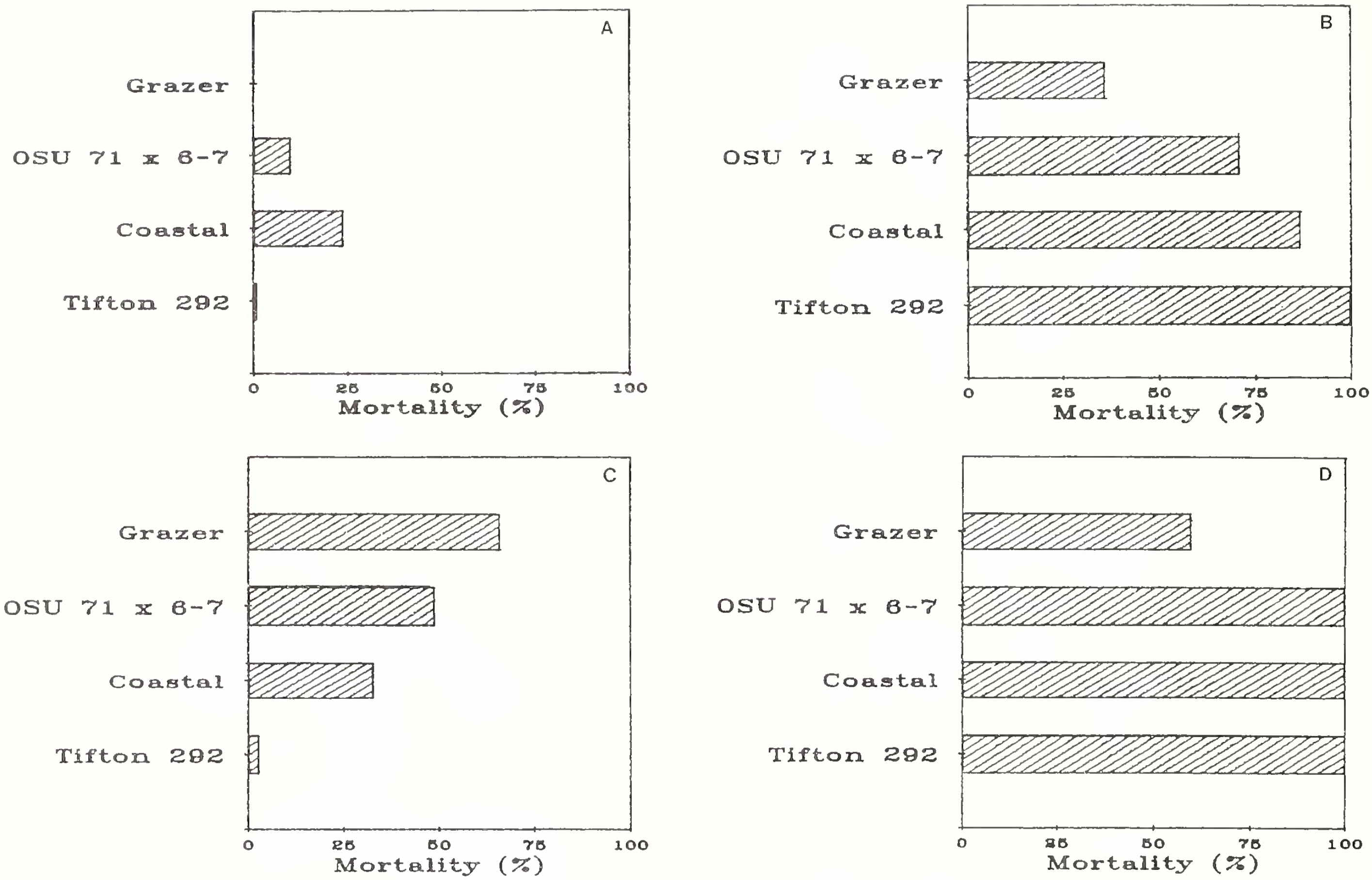

Figure 3.
Mortality of fall armyworm larvae fed artificial diet supplemented with A) water, B) dichloromethane, C) methanol, and D) petroleum ether leaf extracts of bermudagrass (modified from Quisenberry et al. 1987).

VARIATION IN ROOTING CHARACTERS FOR BUFFELGRASS (CENCHRUS CILIARIS L.)

M.A. Hussey[1]

INTRODUCTION

The genetic modification of root systems provides a potential method for improving the adaptation and fitness of plants. However, due to the inherent difficulty in the evaluation of root systems, few plant improvement programs have addressed root system morphology.

Early research with Agropyron spp. has indicated that selection for rooting depth and root elongation rate may be useful in improving stand establishment characters of grasses (7). In this study, results from a greenhouse evaluation of rooting depth were compared with stand establishment data collected under field conditions. Highly significant correlations were obtained (R=0.87) between greenhouse and field results.

While not selected specifically for rooting depth, Coastal bermudagrass (Cynodon dactylon) has been shown to be "deeper rooted" than the other commonly grown warm-season grasses (1, 3). It has been suggested that having a large percentage of roots at depths greater than 3 feet is what contributes to the drought tolerance of Coastal.

Similar results have been reportd for other warm-season grasses. The cultivar WW Spar (Bothrichloa ishaemum) has been observed to respond to rainfall more rapidly than Caucasian Bluestem (Bothrichloa caucasian). Examination of rooting depth for these two species (2) has indicated that the adaptive advantage of WW Spar may be due to WW Spar having a greater root mass at depths greater than 0.8 meters. Similarily, buffelgrass (Cenchrus ciliaris) is regarded as being more drought tolerant than either Panicum maximum or Themeda trianda due to its greater rooting depth (8).

Studies investigating variation in root geometry of grasses have reported that a wide range of variation usually exists for most characters (rooting depth, total root length, root diameter, root number, etc.) (4, 5, 6). It is also apparent from these studies that rooting characters are probably polygenic in nature (4), but estimates of narrow sense heritability are high indicating that plant root systems may be manipulated by traditional plant improvment techniques.

Since the improvement of stand establishment characters as well as the drought tolerance of warm-season grasses is a major objective of forage grass improvement in Texas, efforts at College Station are focusing on the potential to manipulate rooting characters in warm-season grasses. Initial objectives of this program are to 1) determine the variation for selected root characters, and 2) then to determine the adaptive significance of these characters.

MATERIALS AND METHODS

Screening Procedure

One hundred and ten diverse accessions of buffelgrass (Cenchrus ciliaris L.) were evaluated in a greenhouse study to determine the potential range of variability that existed for rooting depth, root elongation rate, and shoot/root ratio. For this study, the accessions utilized were obtained from the Plant Introduction Station, Experiment, Georgia and represented a subset of some 750 accessions that had been previously evaluated in Texas.

Due to the number of accessions involved, the genotypes were evaluated in a series of experiments conducted over 3 months in the greenhouse. Each experiment consisted of 22 genotypes plus the cultivar Nueces. For purpose of data analysis, all genotypes were expressed as a percentage of Nueces.

Each experiment was initiated by transplanting seedlings (3 to 5 tillers) into polyethylene tubes (5.0 cm x 200 cm) filled with fritted clay (particles greater than 10 mm). The plastic tubes were then placed inside PVC pipe, inclined at 15 degrees to the vertical, and the PVC pipe was placed inside an insulated box.

Once per week, the plastic tubes were removed from the PVC pipe and the depth of the fastest growing root marked as it grew along the soil / tube interface. Each experiment was terminated when the first genotype reached the bottom of the polyethylene tubes (generally 4 to 5 weeks).

To harvest each experiment, the plastic tubes were removed and cut into 0.5 m sections. The sections were slit vertically and the roots were washed free of the fritted clay. Roots and shoots were then dried at 60°C for 48 hr. and dry matter determined.

Verification of Procedure

To verify that the screening technique was repeatable, ten genotypes were selected from the initial trials, along with the cultivars Common and Nueces. This comparison was conducted as outlined previously and the relative rankings of the ten genotypes compared with their rankings from the initial experiments.

1/Assistant Professor, Soil & Crop Sciences Department, Texas A&M University, College Station, Texas.

RESULTS AND DISCUSSION

Variation in Rooting Characters

Results from this initial experiment with buffelgrass indicates that a wide range of variability exists within the species for rooting depth, root elongation rate, and shoot to root ratio (Table 1). For all characters examined a bimodal frequency distribution was observed with the cultivar Common not being significantly different from the population mean. The wide range of variability observed for these characters, coupled with the relatively small standard deviations between replications within individual experiments suggest that it should be possible to select for stable rooting characters in buffelgrass.

For all 110 accessions studied, correlations between root mass and shoot mass was highly significant (R=0.78**), while less precise relationships were observed between rooting depth and root mass (R=0.48*) and between rooting depth and shoot mass (R=0.42*). The relationship between tiller height and rooting depth (R=0.07) was not significant.

Verification of Screening Procedure

Evaluation of the 10 selected genotypes, Common, and Nueces indicated that the initial screening procedure ranked 11 out of 12 accessions in the same order (R=0.83) even though the relative magnitude of the numbers obtained were significantly different between studies. It appears that the technique utilized in this study has potential for rapid characterization of germplasm, but that more refined procedures may be required to accurately compare cultivars where small differences occur.

Present research efforts with buffelgrass are focusing on the potential relationships between root system morphology and 1) stand establishment, 2) drought tolerance, and 3) competitive ability to develop selection indicies for use in the improvement of warm-season grasses.

Table 1
Range of variation for selected rooting characters in buffelgrass (Cenchrus ciliaris L.)

	Rooting depth (cm)	Root elongation rate (cm/da)	Shoot/ root
Accessions	63-200	1.8-7.14	0.89-3.43
Common	147	5.25	2.39

LITERATURE CITED

1. Burton, G.W., E.H. DeVane, and R.L. Carter. 1954. Root penetration, distribution and activity in southern grasses measured by yields, drought symptoms and P^{32} uptake. Agron. J. 46:229-233.

2. Coyne, P.I. and J.A. Bradford. 1986. Biomass partitioning in 'Caucasian' and 'WW-SPAR' Old World Bluestems. J. Range Mgt. 39:303-309.

3. Doss, B.D., D.A. Ashley, and O.L. Bennett. 1960. Effect of soil moisture and root distribution of warm-season forage species. Agron. J. 52:569-572.

4. Ekanayake, I.J., J.C. O'Toole, D.P. Garritt, and T.M. Masajo. 1985. Inheritance of root characters and their relations to drought resistance in rice. Crop Science 25:927-933.

5. Hurd, E.A. 1985. Growth of roots of seven varieties of spring wheat at high and low moisture levels. Agron. J. 60:201-205.

6. Jordan, W.R., F.R. Miller, and D.E. Morris. 1979. Genetic variation for root and shoot growth in hydroponics. Crop Science 19:468-472.

7. Kittock, D.L. and J.K. Patterson. 1959. Measurement of relative root penetration of grass seedlings. Agron. J. 51:512.

8. Taerum, R. 1970. Comparative shoot and root growth studies of six grasses in Kenya. E. Afr. Agri. Forestry 36:94-113.

UTILIZING WILD GERMPLASM TO IMPROVE CULTIVATED SPECIES

Wayne W. Hanna [1/]

INTRODUCTION

It is usually easier, faster, and more efficient to manipulate and use germplasm found within the cultivated types of the species being used. Genes from cultivated types can be transferred to commercial cultivars faster because fewer undesirable characteristics are associated with the desirable gene(s) and fewer incompatibility mechanisms are encountered. However, the wild grassy and weedy subspecies and the distinct wild species of cultivated crops can be valuable and untapped sources of germplasm

GENE POOL AND CHROMOSOME CONSIDERATIONS

Gene Pools

The potential success in using germplasm from wild species can best be understood by using the primary, secondary, and tertiary gene pool concept of Harlan (1975).

Wild germplasm of the primary gene pool usually crosses easily with the cultivated species but many undesirable characteristics of the wild germplasm such as seed dormancy, seed shattering, grassy plants, small seed, and small inflorescences need to be eliminated in the backcrossing process. The primary gene pool germplasm usually belonging to grassy or weedy subspecies is the easiest of the wild germplasm to incorporate into the cultivated species.

Crosses between cultivated species and species from the secondary gene pool may be difficult to make and many fertility problems are encountered. The secondary gene pool species are distinct species and either have at least one genome in common with the cultivated species or a large amount of residual genome homology. High interspecific hybrid sterility can be encountered in crosses between species from this gene pool and the cultivated species but this sterility may be overcome by producing amphiploids.

Crosses are usually difficult to make between the tertiary gene pool species and the cultivated species. The success in producing the interspecific hybrids with this gene pool is enhanced by manipulating ploidy levels of the parental species and by using bridging hybrids. There is little homology between genomes, thus, high male and female sterility can be encountered, especially in species reproducing sexually. Amphiploidy may improve or partially restore the fertility of interspecific hybrids.

Chromosomes

As may be expected, germplasm from the wild species with chromosomes homologous to those of the cultivated species is most easily manipulated and transferred. The difficulty in gene transfer increases as the chromosomes become less related and/or when the wild species has more than one genome as in alloploids.

The following are important considerations when attempting to use wild germplasm:

1. Chromosome numbers
2. Chromosome homology
3. Genome number and makeup
4. Genotype of parental species

IMPROVING SUCCESS IN USING WILD GERMPLASM

The germplasm of wild species is difficult to manipulate. The ease of manipulation will vary both within and between species. However, success in transferring wild germplasm to cultivated species can be improved if:

1. Objectives are specific (with some flexibility)
2. Good screening and selection techniques are available for the target characteristics
3. Large populations are studied
4. Characteristic(s) to transfer is highly heritable
5. Multiple cycles per year are possible
6. Alternative methods are tested
7. A team approach is used

USING WILD GERMPLASM AT TIFTON, GEORGIA

The forage and turf program at Tifton, Georgia has successfully used wild germplasm to improve cultivated species and produce new cultivars for a number of years. Part of the success, especially with the secondary and tertiary gene pools, has been due to the fact that use of the end product was not dependent on male or female fertility or seed production such as in the vegetatively propagated perennial turf hybrids. However, in recent years, success has been realized in wide crosses where fertility and seed production are important. The following discussion is only an attempt to briefly describe examples of research resulting in successful use of wild germplasm at Tifton.

Primary Gene Pool

One of the most recent successes has been in the transfer of dominant genes for disease immunity and genes for increased forage yield from _Pennisetum americanum_ (L.) Leeke subspecies _monodii_ (Maire) Brunken, a wild weedy and grassy plant, to pearl millet (Hanna, et. al., 1985). This germplasm transfer research resulted in the release in 1986 of Tifleaf 2 pearl millet, a rust and leaf spot immune forage hybrid. Tifleaf 2 produces up to 20% more forage than Tifleaf 1. The _monodii_ germplasm transfer research has also

1/ Research Geneticist, USDA-ARS, University of Georgia Coastal Plain Experiment Station, Tifton, GA 31793.

resulted in a new stable male sterile cytoplasm and is an excellent source of fertility restorer genes for cytoplasmic male sterility. Tests in two locations in Africa indicate that immunity or high resistance to almost every disease on pearl millet in the world can be found in the monodii gene pool. Monodii was considered a weed along roadsides and around farmer's fields in Africa until our discovery of the rust immunity genes in this subspecies in 1979. Now monodii has become a rich source of genes for improving the cultivated species. The gene transfer research with monodii was greatly enhanced by a team effort, large populations, 3 to 5 generations per years, and efficient screening techniques.

Secondary Gene Pool

Burton (1944) showed that hybrids could easily be made between pearl millet and napiergrass (P. purpureum Schum.). The hybrids had forage potential but were triploid and highly sterile. Later research (Hanna and Monson, 1980) investigated the potential for improving forage yields and quality by using different pearl millet and napiergrass parents. Many of the interspecific hybrids outyielded the best commercial pearl millet hybrids by more than 30%. Additional research in recent years has shown that these interspecific hybrids can be commercially produced in a frost-free climate (Osgood and Hanna, unpublished) and that the interspecific hybrids produce high quality forage late in the fall on which cattle perform well (Hill and Hanna, unpublished).

The pearl millet x napiergrass hybrids are also an excellent source of genes for improving pearl millet, especially for grain production. Doubling the chromosome number of the sterile triploids results in male and female fertile plants (Hanna, 1981) which can be backcrossed to pearl millet. The backcross produces some diploid pearl millet plants with genes for stiff stalk, male fertility restoration, long inflorescences, and leaf morphology from the A' genome of napiergrass (Hanna, unpublished). There appears to be valuable germplasm stored on the A' genome of napiergrass which is not phenotypically expressed until the A' chromosomes are separated from the B genome.

Tertiary Gene Pool

The interspecific Cynodon hybrids produced at Tifton are probably as widely used as wide crosses in any other genus. The successful use of these excellent turf hybrids was possible because they were perennial and could be vegetatively propagated even though they produced no seed.

Most of the turf bermudagrass hybrids such as Tifway, Tifgreen, and Tifdwarf (Burton, 1982) are sterile interspecific triploid (2n = 21) hybrids between C. transvaalensis Burtt-Davy (2n = 18) and C. dactylon Pers. (2n = 36). The sterility is due to both non-homology between chromosomes of the two species and to the simplex condition of the C. transvaalensis genome. These interspecific hybrids combine the fineness of C. transvaalensis with the hardiness of C. dactylon and are the major improved grasses used on golf courses, athletic fields, and recreational areas throughout the tropical and subtropical world.

Transfer of germplasm from the tertiary gene pool to cultivated species becomes more difficult where seed production is important because the lack of chromosome homology results in male and/or female sterility. Sometimes, the initial crosses are difficult to make especially if one species is a diploid and the other is a polyploid. The ploidy barrier can many times be overcome by doubling the chromosome number of the diploid (Dujardin and Hanna, 1983). Progress is being made in transferring genes controlling apomixis from P. squamulatum (2n = 54) to pearl millet (2n = 14) by using induced tetraploid (2n = 28) pearl millet in the backcrossing procedure (Hanna and Dujardin, 1985). Once all chromosomes from the wild species except those with the desired genes have been eliminated, methods other than traditional recombination are needed to transfer the genes. These methods may be chromosome substitution (especially at the polyploid levels) or chromosome breakage and translocation to transfer a piece of chromosome with the desired gene(s). In the future, molecular techniques such as electroporation of protoplasts followed by regeneration may prove to be helpful.

SUMMARY

Wild species can provide valuable germplasm for improving cultivated species. However, the germplasm from wild species is usually not easy to transfer. Wide hybridization can produce hybrids that can be: 1) directly used, 2) used after backcrossing and selection, or 3) used to bridge species through ploidy levels. Overcoming interspecific crossing barriers and finding ways to transfer alien germplasm especially from the tertiary gene pool provides challenges to the plant scientists in the future.

REFERENCES

Burton, G. W. 1944. Hybrids between napiergrass and cattail millet. J. Hered. 35:227-232.

Burton, G. W. 1982. The Tif-turf bermudas. Parks and Recreation Resources 1:9-12.

Dujardin, M. and W. W. Hanna. 1983. Apomictic and sexual pearl millet x Pennisetum squamulatum hybrids. J. Hered. 74:277-279.

Hanna, W. W. 1981. Method of reproduction in napiergrass and in the 3x and 6x alloploid hybrids with pearl millet. Crop Sci. 21:123-126.

Hanna, W. W. and M. Dujardin. 1985. Interspecific transfer of apomixis in Pennisetum. Proc. XV Intern'l Grassl. Cong. pp. 249-250.

Hanna, W. W. and W. G. Monson. 1980. Yield, quality, and breeding behavior of pearl millet x napiergrass interspecific hybrids. Agron. J. 72:358-360.

Hanna, W. W., H. D. Wells, and G. W. Burton. 1985. Dominant gene for rust resistance in pearl millet. J. Hered. 76:134.

Harlan, J. R. 1975. Crops and man. Madison, Wisc., USA: Amer. Soc. Agron. 295 pp.

INTENSITY GRAZING

T. E. Fairbrother[1]

Recently, controlled grazing has become a topic of interest among farmers and researchers. The concept of controlled grazing has been practiced for many years. However, within the last 15 years the development of high energy low impedance energizers has produced a degree of animal control greatly superior to previous electrical fencing systems. This improvement in technology provided a practical means to build low cost fencing systems needed for controlled grazing.

The lower cost of electrical fence systems compared to conventional nonelectric fence systems is due to the difference in animal control strategy between the two kinds of fencing methods. Conventional fencing provides a physical barrier to animal movement. In order to provide long term animal control, all components of a conventional fence must be designed to withstand considerable animal pressure. Electrical fence systems provide a physiological barrier to animal movement. This strategy allows electrical fence systems to be constructed with lighter weight materials because animals respect the shock produced by the energizer and do not contact the fence.

Electrical fence systems can be designed to be either permanent or temporary. The purpose of the fence determines the type of material used for construction. Permanant fencing materials should be designed to last for the lifetime of the fence. If the fence is designed to last thirty years then each component should be designed to last thirty years. A fence that must be replaced because of premature degradation of a component can be expensive. Temporary electric fence components are designed to be light weight and portable. Some uses of temporary electric fence systems have been fencing off surplus pasture for hay production, enclosing hay bales, strip grazing or short term controlled grazing systems.

Energizers

High energy low impedance energizers are designed to meet one of several safety standards such as New Zealand, British or CEE (International Commission on Rules for the Approval of Electrical Equipment) safety standards. The New Zealand Agricultural Engineering Institute (NZAEI) summarized New Zealand's safety standards as follows:

1. Peak output voltage must not exceed 5,000v.

2. Time between each pulse must be at least 0.75 seconds.

3. The quantity of electricity in each pulse must not exceed 2.5 millicoulombs.

4. The instantaneous output current shall not exceed 0.3 amps for more than 0.3 milliseconds.

Consideration is currently being given to increasing the peak voltage to 10,000v and to limit the maximum energy to 8 joules when a 500 ohm resistor is connected across the energizer terminals. The standards also have requirements for isolation between input and output, effects of over voltage on input, insulation, effects of defective components, effects of temperature, strength of outer case, radio interference and so on.

Pulse Behavior

Electrical fence systems are energized by pulses from the energizer. The electrical pulse can be recorded by a oscilloscope which measures changes in voltage with time. Garden (1982) recorded several graphs from an oscilloscope of a pulse from a New Zealand style energizer when wired across the terminals (Figure 1a) and at different distances along a fence. As the pulse traveled down the wire at speeds of 150,000 km/sec, energy was lost due to heating of the wire and small shorts. The loss of energy changed the shape of the pulse and lowered peak voltage (Figure 1b). Voltage loss became more pronounced as the length of the fence increased until either peak voltage was too low to shock an animal or the shock was not strong enough (not enough joules) to cause an animal to respect the fence (Figure 1c).

Ground System

A common cause of poor performance from energizers is an inadequate ground. In order for an electric fence to deliver a shock to an animal, a complete circuit must be formed. The electrical pulse must leave the energizer, travel through the wire, through the animal, return through the ground to the ground rods and back to the energizer. The voltage supplied by the energizer is divided around this circuit in direct proportion to the resistance of each part of the circuit. The resistance contributed by electricity passing through the ground is very small because the current can spread out and

[1]Research Animal Scientist, USDA, ARS, CSRL, Forage Research Unit, Mississippi State, MS

travel through moist layers of earth. However, as the current collects at the ground rods, it travels along a narrower path and resistance develops if an insufficient number of ground rods are used. Higher resistance in the ground system means less voltage and energy available to shock an animal.

The adequacy of a ground system can be easily tested. First, completely short the fence about 100m from the energizer by placing several metal posts in contact with the wire and ground. Then measure the voltage between the earth terminal on the energizer and a wire pushed into the ground and located at least 2m from the ground rods. This measures the resistance of the entire ground system. The voltmeter should read less than 500v for an adequate ground system for present conditions. A measure of voltage between the wire pushed into the ground and the ground rod should be less than 300v. A higher voltage reading means more ground rods are needed. A voltage difference of greater than 200v between these two readings means that the connections are poor or the return wire is under sized.

A ground system can be improved by selecting a site for the ground rods that will always be damp, using a return wire the same gauge as the lead-out wire, using line tap connectors and at least three ground rods placed 3m apart. A test of the ground system can only determine its adequacy under current conditions. Repeated tests of the ground system should be made during the year to insure an adequate ground under all conditions.

Wire

High tensile smooth steel has become the standard for permanent electric fence systems. The most common gauge used is 12.5 but 14 gauge is available. Tests of breaking strength of 12.5 gauge high tensile wire showed that breaking strength varied from below 1300 lbs to over 2000 lbs depending on the manufacturer of the wire. Breaking strength of all high tensile wire is much higher than the breaking strength of soft steel 12.5 gauge two ply barbed wire (about 950 lbs). The galvanizing used on the surface of high tensile wire is normally class III galvanizing which contains .80 oz of zinc per square foot of wire compared to .30 oz of zinc per square foot of wire for class I galvanizing on some conventional fence wire. Testing has shown that in a dry environment it took 11 years for rust to appear on class I galvanized wire, whereas class III galvanizing took 33 years before rust developed (Anonymous, 1980).

An important property of wire used in an electrical fence installation is its ability to conduct electricity or the resistance of the wire. Wire resistance is directly proportional to length and inversely proportional to the cross-sectional area of the wire. Therefore, doubling the length of wire will double the resistance and reducing wire diameter from 12.5 gauge to 14 gauge will increase the resistance 1.56 times. For long distances the resistance of the wire can be halved by connecting wire of the same diameter in parallel. The resistance of wires used for electric fencing is shown in Table 1 (Anonymous, 1985). The measure of resistance in this table is the resistance in ohms per kilometer to a direct current. The resistance to an electrical pulse would be somewhat greater because of magnetic properties of the wire. The resistance for 6 strand electroplastic twine is much greater than the resistance for 12.5 gauge high tensile wire because of the small diameter wire used in electroplastic twine.

Table 1. Direct current resistance of wire used in electric fencing.

Wire	Resistance Ohms/Km
12.5 g High tensile	35.0
14.5 g High tensile	52.0
10 g Aluminum	4.5
6 Strand Electroplastic	7500

Temporary electric fencing wire is typically made of 15 to 18 strands of plastic woven together for strength with either 3, 6, or 9 strands of stainless steel wire woven with the plastic strands to carry the electrical pulse. Electroplastic twine can be rolled up on a reel to provide quick instillation and removal. A variation of this wire is called hot tape. It is made of plastic strands woven into a ribbon 1/2 or 5/8 inch wide with 5 or 6 stainless steel wires to carry the pulse. The wide ribbon makes this wire much more visible than other wire. Another type of temporary fence wire is a cable made of 7 strands of 24 gauge soft steel class III galvanized wire. The steel cable has a diameter about 15 gauge and has much lower resistance than electroplastic twine so that it can be used for longer distance fences.

Insulators

Insulators used for electrical fence systems are made in a variety of colors, shapes, material and durability. Some insulators were designed for electric fence systems powered by older type fence chargers and for temporary fence. These insulators served their purpose well. However, insulators used for permanent electrical fence systems and low impedance energizers must cope with long exposure, higher wire tensions, and higher voltages than older fence systems. Research conducted by NZAEI suggested that plastic formulations that contain ultra-violet light inhibitors and antioxidants showed much improved durability than plastics without these additives. These additives should be added at the time of synthesis of the plastic rather than at the time of moulding. Also, insulators made from recycled plastic are less durable. Unfortunately, it is impossible to determine how a new insulator was made by its appearance. Another option to insulators are plastic or fiberglass posts. However, the plastic used in either type of post should be selected with the same durability characteristics as for moulded insulators. Fiberglass posts can be found from 3/8" diameter for portable fences to 1" diameter for permanent fences.

Wood Posts

Wood posts have been used in electrical fence systems primarily as braces or at locations where small diameter posts pull out of the ground. Wood posts are typically treated with a preservative to prevent rotting. The most frequently used preservatives are creosote, pentachlorophenol and waterborne preservatives such as chromated copper arsenate (CCA). The preservative can be applied by painting, cold soaking or pressure treatment. Little et al. (1978) did not recommend painting as a method for applying preservative to wood posts or any wood in contact with the ground. The American Wood Preservers Association has developed standards for pressure treated wood posts. For wood posts the following standards are applicable: waterbourne preservatives AWPB LP22, creosote AWPB LP55 and pentachlorophenol AWPB LP33 or AWPB LP44. Posts treated to these standards are normally stamped or tagged with a AWPB quality stamp and can be expected to last 25 years.

The decision to adopt electric fencing must also bring with it the commitment to make it work. It must be accepted that electric fencing will require more routine maintenance than conventional fencing. However, a critical step towards the success of an electrical fence system is the choice of components. The opportunity to use low cost components should not be an excuse to use "cheap" components. Reliability will ultimately determine the cost of the fence. This will be especially true as the number of subdivisions and the complexity of pasture systems increase. The control of animals with relatively low cost electrical fencing will increase opportunities for good pasture management tremendously.

Literature Cited

1. Anonymous. 1980. How to build fences with USS Max-Ten 200 High tensile fence wire. No. T-111575 U. S. Steel Corp, Pittsburg, PA.

2. Anonymous. 1985. New Zealand Agricultural Engineering Institute Electric Fencing Notes. Extension Officer New Zealand Agricultural Engineering Institute, Lincoln College, Canterbury, NZ.

3. Garden, G. M. 1982. Electric fencing - the critical components. Proceedings Ruakura Farmers Conference. Wellington, New Zealand.

4. Little, R. L., F. G. Wagner, Jr. and H. O. Beals. 1978. Preservative treatment of posts, timber and lumber. USDA Forest Service General Rpt. SA-GR2.

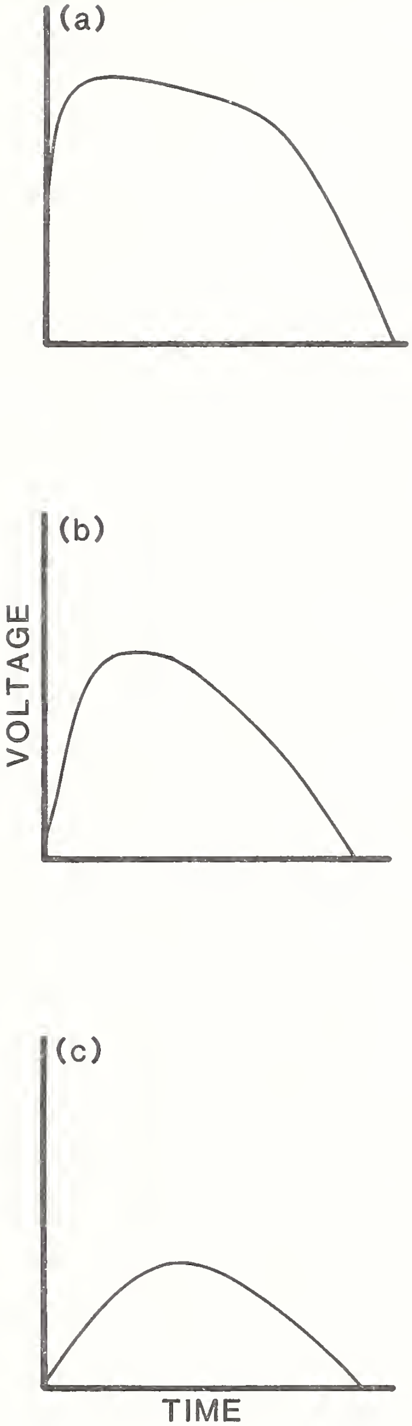

FIGURE 1. Pulse shape at the energizer(a), at some point along the fence(b) and at a point where normal losses have occurred(c).

PRINCIPLES AND CONCEPTS OF SHORT DURATION GRAZING ON SEMIARID RANGELANDS

Rod Heitschmidt[1]

Although short duration grazing is not a new concept in grazing management, interest in its application on the arid and semiarid rangelands of the world has increased dramatically in the past decade. This interest stemmed primarily from the claim that proper implementation of a short duration grazing system would permit one to substantially increase rate of stocking. This purported increase was attributed primarily to the anticipated positive effects that short duration grazing would have on herbage production. This claim was made, however, in the absence of supporting scientific evidence. Thus, in 1981 we initiated a series of studies designed to quantify the effects of a 16-paddock, rotationally grazed (RG) system on quantity and quality of forage produced and consumed, watershed condition, grazing behavior of cows, cow/calf production, and economic returns.

Yearlong grazing treatments included in the study were the very heavily stocked, cell-designed RG treatment, continuous stocking at heavy (HC) and moderate (MC) rates of stocking, and a 4-pasture, 3-herd deferred rotation system (DR) stocked at a moderate rate. Breed of cows was Hereford-Angus cross. Breed of sire was Charolais. Stocking rates were 9, 12, 15, and 15 ac/cow/yr in the RG, HC, MC, and DR treatments, respectively. Total numbers of cows per treatment were 125, 100, 82, and 75, respectively. Because of labor constraints, intensive studies examining biological processes were conducted in the RG and MC treatments only; however, livestock production parameters have been, and continue to be, monitored in all four treatments.

Results from these studies have clearly shown that the short-term (< 5 years) effects of the RG treatment on those parameters examined were closely linked to rate of stocking and paralleled the results anticipated in any heavily stocked grazing treatment. In general, the studies showed that:

1. Quantity of herbage standing crop was less in the RG than MC treatment.

2. Quality (% CP and % OMD) of herbage standing crop was greater in the RG than MC treatment because amount of low quality (senesced) herbage was less in the RG than the MC treatment.

3. Diet quality in both treatments was equal.

4. Nutrient intake was greater in the MC than RG treatment during critical times of the year when herbage standing crop was low.

5. Water infiltration rates were less and sediment production was greater in the RG than MC treatment immediately following a grazing event although they were similar immediately prior to a grazing event.

6. Cows generally walked about one mile/day farther and grazed one hour/day less in the RG than MC treatment.

7. Grazing selectivity for various plant communities was equal in the two treatments.

8. Density of cow trails was greater in the RG than HC, MC, or DR treatments.

9. Production/cow was least in the RG treatment because of reduced weaning weights and weaned calf crops. However, production/ acre was greatest in the RG treatment because rate of stocking was greatest.

10. Economic returns were least in the RG treatment because individual cow performance was least.

Based on these findings, and those from other studies conducted on semiarid rangelands, it was concluded that implementation of a RG-type system does not inherently provide an immediate opportunity to dramatically increase rate of stocking. The results, however, do not refute a hypothesis that some increase in carrying capacity can be expected both on a short- and long-term basis. An increase on the short-term may occur as a result of spatial redistribution of livestock grazing. Because a strong argument can be made that a moderately stocked RG treatment will enhance successional processes, we hypothesize a long-term increase in carrying capacity can be expected as range condition improves.

In retrospect, the results from these studies are not surprising. The basic principle of grazing management is control of the frequency and severity of defoliation of individual plants. Proper control is that which enhances harvest efficiency without causing forage production to decline while meeting or surpassing the nutritional requirements of the grazing animals. The major manipulative factor affecting frequency and severity of defoliation is grazing pressure which may be defined as forage demand per unit of forage available. Theoretically, rotational-type grazing systems provide greater control over frequency and severity of defoliation of individual plants than less intensively managed grazing systems. For example, under continuous, deferred rotation, seasonal, etc. type grazing systems

---

[1]Texas Agricultural Experiment Station, Texas A&M University, Vernon, TX 76384

pressure. However, in an intensively managed RG system, grazing pressure can be adjusted by adjusting stocking rate, livestock density (number of paddocks), and/or rate of rotation (length of graze/rest period). Thus, at least in theory, we can argue that RG offers a realistic opportunity to enhance forage and ultimately livestock production.

Why then, are the results from our study in conflict with established theory? Quite simply, it is because we are working in a semiarid environment where the overriding factor affecting forage production is precipitation and without adequate precipitation, timely defoliation regimes have minimal impact on forage production. Any grazing regime whose success is dependent upon a positive, postdefoliation forage growth response every time a plant is defoliated will fail in a semiarid environment because herbage growth is disjunctive rather than continuous. Furthermore, number of failures and/or length of operative time prior to failure, will be positively and closely linked to rate of stocking. The results from our study clearly show that failure to accumulate reserve forage for livestock consumption during periods of adverse growth was the major factor limiting our success. Successful grazing strategies are those that function within the bounds of the biological and physical laws of nature and not those that are designed to "override" the effects of these laws.

A second major factor affecting the relative success of a RG system is related to level of managerial expertise. Grazing pressure in a RG system, relative to the grazing animals, is directly proportional to number of paddocks. For example, assume a herbage standing crop of 2000 lbs/acre in both a continuously grazed pasture and a 10-paddock RG system stocked at equal rates. Assuming forage production is not affected by grazing treatment, then average grazing pressure for the entire grazing season would be equal in both treatments relative to the forage component but tenfold greater in terms of the livestock. This example clearly shows why individual animal performance is often depressed in a RG system and why level of depression is particularly responsive to managerial skills. The opportunities for "mismanagement" in a RG system is directly related to number of paddocks and the probability that every management decision will be correct is an inverse function of rate of stocking and desire and ability of management personnel.

In conclusion, I believe the potential benefits from rotational grazing are greatest in regions where potential forage production is high but limited by canopy shading (i.e. extended growing season, moderate to high levels of precipitation, and limited variability in temporal rainfall patterns). Moreover, I believe the rotational grazing system will decline as plant species' diversity increases and as level of managerial skill declines. In other words, the potential benefits from rotational grazing are greatest in those situations where spatial and temporal control of the frequency and severity of defoliation of individual plants can enhance the quantity and quality of forage both produced and consumed.

PHOTOSYNTHESIS AND GROWTH OF PASTURES AS INFLUENCED BY DEFOLIATION

R. H. Brown[1/]

Close, continuous defoliation of pastures reduces forage production. With the development of the leaf area index (LAI) concept it was widely accepted that pasture management could be improved by maintaining sufficient leaf area to intercept 95% of solar radiation. Efficient harvest of foliage by continuous grazing tends to maintain pastures below the optimum LAI and therefore grazing management is a compromise between high LAI for light interception and efficient utilization of forage produced.

Systems of rotational grazing have been advocated for many years as a way of more efficiently utilizing forage produced. Rotational grazing is advantageous in maintaining yields of species which are particularly susceptible to close, continuous defoliation. It is also useful in the separation of animals based on nutritional needs as in systems of "forward creep grazing" and "top and bottom grazing". However, in most studies animal production per unit area is only slightly higher under continuous rotational grazing (3). The purpose of this discussion is to examine some aspects of grazed pastures in an attempt to explain the influence of defoliation on pasture productivity.

Frequent defoliation reduces yields of most species as is shown for 'Coastal' bermudagrass in Table 1 (4,5). Total biomass for plots mowed weekly to a 6 cm height was only one-third of that cut monthly at the same height. The lower yield for weekly cut plots is related to (1) the lower LAI, which did not reach an optimum during the season and (2) lower apparent photosynthesis (AP) in weekly cut plots at equivalent values of intercepted radiation (Table 1). The lower AP at equal radiation interception was apparently due to a higher proportion of non-photosynthetic tissue or less efficient leaves in the weekly cut plots. During the first week after cutting, AP in the monthly cut plots was lower than in weekly cut plots because all leaves were removed. However, in weeks 2, 3 and 4 AP in monthly cut plots was much higher than in plots cut weekly.

The growth and carbon balance in grazed swards cannot be simulated very well in mowed plots but increased intensity of defoliation by grazing has effects similar to frequent cutting on growth and photosynthesis. It was found that perennial ryegrass under "hard" continuous grazing to maintain an LAI of about 1 exhibited less groww photosynthesis than when "leniently" grazed to maintain an LAI of 3 (Table 2) (7). The higher gross photosynthesis under lenient grazing was attributed mostly to more complete light interception; photosynthetic capacity of leaves was actually higher under hard grazing (2).

Death and decay of forage tissues is a major loss of dry matter in pastures with high LAI. Although an LAI of 3 is not considered high, Parsons et al (6) estimated that 42% of gross photosynthesis was lost due to tissue death in swards maintained near this LAI value (Table 2). Rotational grazing has been considered as a way to increase productivity by utilizing higher LAI and harvesting before substantial tissue death occurs.

The physiology of forages may be quite different under continuous and rotational grazing. King et al (1) found that AP of perennial ryegrass responded differently to LAI under continuous and rotational grazing. AP was a linear function of LAI from about 1.5 to 5 under continuous grazing, but responded in a curvilinear fashion as rotationally grazed pastures regrew from LAI of about 1 to 6.5 (Fig. 1). Over the LAI range encountered in continuous grazing, AP was similar for the two. During the grazing down of the rotationally grazed pasture AP was a linear function of LAI, but was substantially lower than for continuously grazed or regrowing swards. From this it may be suggested that grazing time should be as short as possible in rotational grazing. The authors estimated that if the grazing time was 7 days and regrowth 21 days, then a rotationally grazed pasture would be equally productive to a continuously grazed one kept at an LAI of about 3.5. Parsons et al (7) found that under rotational grazing photosynthetic production was slightly greater than under lenient continuous grazing even though stocking rate was similar to that of hard continuous grazing (Table 2).

As emphasized by Parsons et al, however, photosynthetic production is only one-half of the problem. Although rotational grazing increased total gross photosynthesis by more than 50% over hard continuous grazing, animal intake was similar (Table 2). This means that the photosynthetic products were consumed more efficiently (25%) under hard continuous than rotational grazing (17%). One reason given for lower efficiency of rotational grazing was death of tissue toward the end of the regrowth period. Another was the variability in the extent to which dry matter accumulated during regrowth was removed by grazing animals. The forcing of consumption of low quality residues can be a negative factor in consideration of rotational grazing.

In conclusion, although plant productivity can be increased by increasing LAI and by rotational grazing, those grazing management systems which maximize plant productivity tend to reduce utilization of forage produced.

[1/] Department of Agronomy, University of Georgia, Athens, GA 30602

Literature Cited

1. King, J., E.M. Sim and S.A. Grant. 1984. Photosynthetic rate and carbon balance of grazed ryegrass pastures. Grass Forage Sci. 39:81-92.

2. Leafe, E.L. and A.J. Parsons. 1983. Physiology of growth of a grazed sward. Proc. 14th Inter. Grassl. Cong. Westview Press Inc., Boulder, CO. pp. 403-406.

3. Matches, A.G. and J.C. Burns. 1985. Systems of grazing management. In. Forages: The Source of Grassland Agriculture. M.E. Heath, R.F. Barnes and D.S. Metcalfe (Ed.). Iowa Univ. Press. Ames, IA. pp. 537-547.

4. Morgan, J.A. and R.H. Brown. 1983. Photosynthesis and growth of bermudagrass swards. I. Carbon dioxide exchange characteristics of swards mowed at weekly and monthly intervals. Crop Sci. 23:347-352.

5. _______________ II. Growth patterns as estimated by harvest and gas exchange techniques. Crop Sci. 23:352-357.

6. Parsons, A.J., E.L. Leafe, B. Collett, P.D. Penning, and J. Lewis. 1983. The physiology of grass production under grazing. II. Photosynthesis, crop growth and animal intake of continuously-grazed swards. J. Appl. Ecol. 20:127-139.

7. Parsons, A.J., E.L. Leafe and P.D. Penning. 1982. Proc. Efficient Grassland Farming. Occasional Symp. No. 14, Brit. Grassland Soc. pp. 145-147.

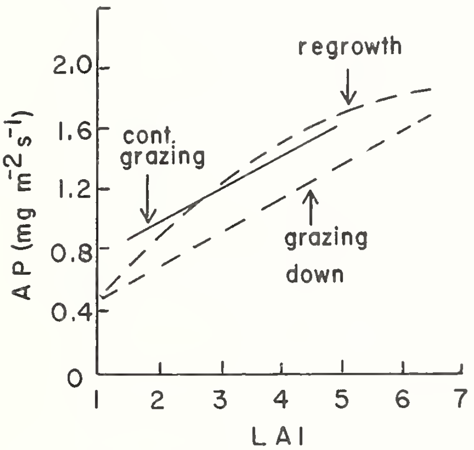

Figure 1. Relationships between apparent photosynthesis (AP) and LAI for perennial ryegrass swards under continuous grazing and during regrowth and grazing down of rotational pastures. Redrawn from (1).

Table 1. Yield, LAI and apparent photosynthesis (AP) of bermudagrass swards cut at weekly and monthly intervals (4,5).

	Weekly	Monthly
Yield (T/ha)1/	7	21
LAI	0.9-3.5	0-10
AP (mg m^{-2} sod s^{-1})2/	1.08	1.40

1/ Total biomass gain (Tops + roots) from 20 June to 1 Oct.

2/ Calculated values for 1,000 μmol $m^{-2}s^{-1}$ of intercepted photosynthetic photon flux density.

Table 2. Gross photosynthesis, animal intake, and tissue death losses in perennial ryegrass pastures (6,7).

	Continuous		Rotational
	Hard	Lenient	
Stocking rate (sh/ha)1/	47	24	45
LAI	1	3	--
Gross photo. (T/ha/yr)	37.6	54	58
Animal intake (T/ha/yr)	9.6	6.9	9.8
% Harvested	25	13	17
% Death loss	26	42	--

1/ Stocking rate in No. of sheep per hectare.

APPLICATION OF CONTROLLED GRAZING PRINCIPLES

by Curtis W. Absher[1]

"Graze-More-Beef" is a demonstration program to highlight the factors that improve the productivity and utilization of pastures by beef cattle. The objective of the demonstrations is simplified into the question, "How many pounds of gain can you produce per acre of pasture?" Once the challenge of answering this question has been accepted then many educational opportunities become available, and teachable moments are created. Questions relating to soil fertility, forage specie and variety selection, fence construction and location, water quality and availability, grazing management, stocking rate, stocking density, price margins, animal health and parasite control all suddenly take on relevance.

The Graze-More-Beef Program began as a 4-H project that was developed by agronomists and animal scientist. A 4-H project was considered the proper way to start the program because of the detailed information that was desired. It was thought that parents would help their children fence small plots, obtain cattle weights at frequent intervals and do the extra things to make the learning experience complete for the child while such a demonstration would be too much trouble to get the adult to do for his own benefit. So the 4-H project was developed and piloted in south central Kentucky in the early 70's. It was a successful educational program while intensively managed by specialist, but large numbers of youth were never directly involved. Extreme price fluctuations and the "economic glamour" of other crops seemed to push the effort into dormancy during the mid and late 70's.

Graze-More-Beef resurfaced as a result demonstration in pasture utilization in 1983. The impetus was the need to verify (under field conditions) a computer model developed by the College of Agriculture. The single project in 1983 provided evidence that there was much interest in improving pasture utilization and that there were likely several producers willing to study grazing management on their own farms. Growth in the number of projects and distribution has confirmed this belief. In 1984, three projects were conducted, 10 in 1985 and 15 in 1986. Early demonstrations were conducted mostly on established fescue and fescue/clover pastures. In 1986, the scope of the program was expanded to include 3 alfalfa grazing demonstrations and one demonstration on reclaimed surfaced-mineral land. The results of 4 years of demonstration work are given in the table.

1/Department of Animal Sciences, University of Kentucky, Lexington, Kentucky 40546.

Graze-More-Beef Demonstrations

Year	Pasture	No. Demo	St. Rate	No. Paddock	Live Weight gain/acre Partial	Live Weight gain/acre Full Season
1983	Grass/clover	1	1.75	4.0	280	--
1984	Grass/clover	3	2.1	2.3	320	428
1985	Grass/clover	10	2.6	4.7	251	484
1986	Grass/clover	11	2.5	9.1	298	579
	Alfalfa	3	4.12	7.3	535	874
	Reclaimed Mine Land	1	.38	5.0	83	--

"Graze" is the key word in Graze-More-Beef demonstrations. Understanding the principles of grazing management is a major reason for the effort. Therefore, all efforts are directed at emphasizing the harvest of pasture by grazing rather than by any type of mechanical harvest. While agronomists and animal scientists have discussed the merits and demerits of put-and-take methods of pasture utilization, a modified put-and-take method was recommended in this program, that is, high stocking rates were advised early in the season with reductions as needed throughout the season. The stocking rates given in the table represent the initial stocking rates. These rates were generally reduced to 1/2 this rate about July 1 in most demonstrations.

While Graze-More-Beef is a demonstration of principles of controlled grazing, economic considerations are of vital importance to the producer. A danger is recognized in emphasis on pounds of beef per acre. Maximum pounds of live weight gain will probably not yield maximum profit in most situations. But to this point, emphasis on pounds per acre has not pushed most producers into the economic zone of diminishing returns. Economic hazards of Graze-More-Beef are considered to be: 1) Extreme price fluctuations, 2) poor cattle performance, 3) drought and 4) under utilization of pastures. With these economic hazards in mind the following guidelines have been developed:

1) If feeders must be purchased in the spring do so three weeks to a month before pasture is ready to be grazed.
2) Condition feeders by treating, vaccinating, and feeding a nutritionally balanced ration.
3) To assure effective pasture utilization, stocking rates in the early season should be two to three times the expected carrying capacity during July and August.
4) Concentrate cattle into paddocks that they can utilize in 3 to 7 days. Pastures generally need 25 to 30 days of rest. Therefore five to ten pastures are needed as a minimum number of paddocks to begin controlled grazing programs. Generally, more paddocks are needed later in the season to allow for more rest time for each paddock.

5) Reduction in cattle numbers in late June or early July is necessary to avoid critical reductions in animal performance. A "summer slump" on most pastures will be experienced but if gain can be kept above 1.25 to 1.5 pounds per day during mid summer, improved fall gains will keep the overall gain at a profitable level.
6) Final sales of cattle are likely to be in late October or early November. Try to avoid selling on glutted markets.

Detailed economic analysis was possible on eight of the 1986 projects. Net return per acre ranged from $15 to $257 with an average of $102.

Suggestions for conducting Graze-More-Beef Demonstrations are:

1) Any amount of pasture area but 3 to 30 acres is recommended. It appears that success is better if only a portion of a farm is utilized the first year. This gives all people a chance to get the hang of the demonstration such as appropriate stocking rates, fence location, design, and etc.
2) For the first year a very simplified demonstration seems to work best. This means that growing cattle, heifers, steers, or bulls, harvest the pasture while it grows. Considering health and efficiency, cattle should weigh from 400 to 600 pounds at the start of the grazing season. The range in the initial stocking rate per acre should be between 2 and 5 head per acre.
3) A minimum of 4 paddocks is recommended, but 8 is preferred. Increases in efficiency may result if more paddocks are used. If 4 or 8 paddocks are layed out with permanent or fixed fences, then the number of paddocks can be doubled by dividing paddocks with temporary fences.
4) Weights should be taken when the cattle go on pasture (April 10 - May 1), July 1 ± a week, and at the end of the grazing season. Also, if cattle are removed at other times, it is desirable to get weights, especially on smaller projects. In order to keep your demonstrator's and his neighbor's interest high during the project, weights taken every 4 to 6 weeks and adequately publicized will help. On larger projects, a sample of grazers can be designated as "tester" cattle. These animals could be sorted out and weighed and their data used to calculate average daily gain. Average daily gain multiplied by animal grazing days per acre is a good estimate of pounds per acre produced.
5) Signs, newspaper stories, posters, tours and field days are all good ways to get information to the public.

Signs which say [GRAZE] [MORE] [BEEF] spaced on fence posts along the road are a simple way of identifying the demonstrations. A neat sign giving Cooperative Extension Service identity is also desirable along with other sponsor signs used in good taste.

Don't have a field day or tour without recent weights. That is the first interest of participants. You can incorporate other subject matter information once this requirement is met.

6) Other information which is interesting to collect is forage production and utilization. This can be obtained by the use of pasture cages or various pasture instruments. Assistance from agronomists will be necessary to carry out this step.
7) A complete record of all expenses is necessary to complete the economic story. Time and goods used should also be given a value if expenses are not actually incurred.

Literature Cited

Absher, C. W., C. J. Kaiser and L. W. Murdock. 1972. Graze-More-Beef 4-H Project Manual. Univ. of Ky., College of Agriculture, Cooperative Extension Service. 4-H 1306.

Turner, L. W., C. W. Absher, J. K. Evans. 1986. Planning Fencing Systems for Intensive Grazing Management. Univ. of Ky., College of Agriculture, Cooperative Extension Service. ID-74.

REPORT ON THE STATUS OF A NEW SOUTHERN REGIONAL PROJECT

D.G. St.Louis[1], D.C. Huffman[2], and C.P. Bagley[3]

On October 22, 1986, in Starkville, Mississippi, the Southern Research Development Committee (SRDC) 86-03 was formed to develop a new regional project. Participants were those at the final meeting of Regional Projects S-156 and S-167. A draft project proposal entitled "Development of Profitable Beef-Forage Production Systems for the Southern Region" was presented by a writing committee of the Regional Projects. Discussion led to further revisions that were presented at the second meeting of SRDC 86-03 on February 4, 1987, at Nashville, Tennessee.

The general project objective is to "develop and evaluate beef-forage production systems to enhance profit and optimize resource utilization." Specific objectives are to: (1) Define soil-plant-animal-environment interrelation-ships to improve grazing management practices associated with major forage species combinations and beef production systems. (2) Define technologically feasible beef-forage management systems that are economically viable and applicable to major ecological areas of the South. (3) Refine and enhance plant and animal simulation models to improve their accessibility and extend their applications.

Simulation models seem to be the common focus for tying together the contributions of the various institutions into a regional effort. Some institutions will be involved in experimentation to aid in model development and refinement while others will be model users aimed at determining the adequacy of and changes needed in the models. Some institutions will adapt simulation models for use on microcomputers. A procedure for coordination and transfer of data and information between participating model developers and model users will be included.

This regional project is presently being revised to better identify cooperative efforts among the states and is scheduled to begin October 1, 1987 if the Southern Directors and Committee of Nine approve it. Interested scientists should contact their representatives to SRDC 86-03 if they have not already made a specific commitment to the project. The project leaders are: Arkansas, Otto Loewer; Georgia, Gary Hill; Kentucky, Ed Smith; Louisiana, Donald Huffman; Mississippi, David St. Louis; Oklahoma, J. Oltjen; South Carolina, Dee Cross; Texas, Jerry Baker; Virginia, J.P. Fontenot; ARS-Booneville, M.A. Brown; ARS-El Reno, Sam Coleman; ARS-Watkinsville, Maurice Frere; and ARS-Mississippi, Timothy Fairbrother.

1/South Mississippi Branch Experiment Station, Poplarville, MS 39470.
2/Department of Agricultural Economics and Agribusiness, Louisiana State University, Baton Rouge, LA 70803-5604.
3/Rosepine Research Station, Rosepine, LA 70659.

EXPERIENCES WITH CONTROLLED-ROTATION GRAZING OF COOL SEASON FORAGES

R.L. DALRYMPLE[1/]

The cool season forages of our region are primarily the various small grains which may include mixtures of annual ryegrass or winter annual legumes. Most of the information herein pertains to mixtures of forage cereal rye + hard red or soft red winter wheat + annual ryegrass. The same basic approaches to production and controlled-rotation grazing apply to other annual cool season forages but stocking rates and other inputs have to be adjusted to meet the expected forage production.

Controlled-rotation, as we use it, is "thoughtful-rotation grazing" whereby all grazings and grazing rotation are done through a regular decision making process based on prior set forage and stock goals which can be managed to the limit of the manager. Grazing and rotations are not precisely preset in the long-term by days, dates, or prior experience. Much planning, thought, and flexibility is employed.

The forages have little quality problems. The basic forage idea is to use controlled-rotation grazing to advance yield as far upward as feasible in a long-term, practically applied rotation-grazing approach. This then, in turn, advances cost efficiency per stock production unit to the limit for that particular forage approach.

The majority of our controlled-rotation grazing experience, demonstration, and research is aimed directly at extension to the producing grazier. During the mid 1960's some of our cooperating producers were using up to 6-paddock cells for cool season forages. Our present day approaches are an outgrowth from those experiences plus incorporation of applicable information from any source. Space does not allow the reporting of research data for the support of controlled-rotation grazing, but it is important and commonly understood and accepted. The approach and information discussed following is based heavily on our demonstration, research, and evaluation on the Pasture Demonstration Farm near Ardmore, Oklahoma and recent application of the approach on other farms of the region.

Our cool season annual cells are managed through the broad inputs of: (1) Programming production; (2) Projecting and allocating that expected production over the days of fall phase and then the spring phase; (3) Setting expected average daily stocking rates at pounds/acre; and (4) Managing the forage and stock within the basic pre-determined goals.

The fall phase and spring phase production are essentially two separate crops due to the vast difference in growth type and regrowth speed. These phases are managed somewhat differently due to those differences.

We have found through research and grazier experience that the vast amount of expected controlled-rotation grazing advantages can be captured by using a 6-paddock fall phase cell and a 12-paddock spring phase cell. This is with one herd and consideration of acceptable labor flow and other considerations. Added paddocks are satisfactory if precise and timely decision making and action upon the decisions is possible.

During usual circumstances fall phase grazing is not initiated until: (1) The forage is over 8 inches tall and up to over 18 inches tall with a useable yield of up to over 2,000 pounds/acre; (2) It is about 6+ weeks post emergence; (3) Well rooted; and (4) Well tillered and actively growing. Climate and production inputs dictate some adjustments.

The basic plan for grazing the fall phase forage is to: (1) Accumulate the fall phase forage; (2) Prorate the use of this accumulation and expected regrowth throughout the fall phase; (3) Top graze the forage during 3 to 4 grazing periods; and (4) Graze to the presently recommended minimum residue height only once, preferably about March 1±.

The basic plan for grazing the spring phase forage is to: (1) Allow initial accumulation to insure a 21-day recovery period; (2) Graze the forage to a 3 to 5± inch residue each grazing period; (3) Set and adjust stocking rates to meet those plans.

Our cool season mixtures are produced at an upper level. Fall phase stocking rates average 625± pounds/acre/day for 120± days. Spring phase stocking rates average 1250± pounds/acre/day for 100± days.

Stock density (head and weight/acre within a given paddock being grazed) to reach most grazing objectives should be 5000± pounds/acre during the fall phase and 17,500± pounds/acre during the spring phase. These densities allow us to achieve acceptable grazing periods of 4± days in the fall phase and 2± days in the spring phase, acceptable to superb grazing uniformity, and acceptable to superb recovery periods.

These densities, and proper stocking rates for the season, allow us to manage for the desirable 30- to 60-day fall phase recovery periods using a top-graze technique and 21± day spring recovery periods using a residue height technique. Fall phase minimum residue heights are presently 3 inches while spring phase minimum residue heights are 3 to 5 inches. Final residue (stubble) left to re-incorporate into the soil will be 5± inches (1200 to 1500 pounds/acre).

[1/] Pasture & Crop Management Specialist, Agricultural Division, Noble Foundation, P.O. Box 2180, Ardmore, Oklahoma 73402.

Recovery periods are greatly influenced by the volume of residue left after any grazing period. The shorter the residue, the less the recovery, and the longer to get it.

Trample control of these lush forages is the number one management problem. Enactment of trample control may be due to wet soils, freeze storms, ice storms, snow cover, or other factors. There are several management inputs, from the initial planning to the most intensive problem, that can be enacted. These are: (1) Choose land/soil with less potential problem (even one paddock of the cell will help); (2) Use reduced shallow but acceptable tillage throughout the major cell; (3) Plan a firm base "abuse-paddock" to use in crisis times to save the main cell; (4) Plan for a firm base lo-till or no-till (not sodseeded) paddock(s) to rotate to as feasible; and (5) Plant as thick as feasible. Then when trample control must be enacted decide which is best and act fast: (1) Rotate faster (maybe more than once daily); (2) Rotate to the firmest main cell paddock(s) from base paddocks; (3) Rotate to the lo-till or no-till paddock(s); (4) Rotate to the abuse paddock, sacrifice it if necessary; (5) Limit graze and use any choice with it from above; (6) Abandon rotation for a time, spread the stock among "all" available paddocks; and (7) Under extreme crisis, abandon the whole approach for a time and place stock in another area. <u>It may be difficult for some to accept, but part of controlled-rotation grazing is the thought process and choice to abandon ship for a time, regroup as new opportunity comes, and proceed with the best way to graze that we know</u>.

Our results of unreplicated demonstrations show little difference in the fall phase between "good continuous" grazing and controlled-rotation grazing. This is very understandable when considering our methods used in both approaches and the fact that 50%± of the fall phase grazing season is too cold or too inadequate photoperiod for good recovery. However, what is done to the forages during the fall phase dictates to a degree what recovers and produces during the spring phase.

Data to date shows the spring phase controlled-rotation grazing compared to good continuous grazing produced the same ADG (2.5 pounds/day), 263 pounds/acre/day more stocking rate (+26%) and 87 pounds/acre more beef/acre (+26%) for a one time interior cell fencing cost of less than $10/acre.

Some grazing rules not to be broken: (1) Never graze shorter than the preset minimum residue height; (2) Never seriously reduce recovery period length; (3) Always manage against trample damage; (4) Never graze all of the fall phase forage in one grazing period; (5) Always finish stock on the best paddock; and (6) Always leave a useful conservation residue to reincorporate.

WHAT AM I LOSING BY REMOVING ENDOPHYTE FROM TALL FESCUE

Malcolm R. Siegel, Lowell P. Bush, Douglas D. Dahlman[1]

Fungal endophytes now appear to be common inhabitants of grasses. These clavicipitaceous fungi belong or are related to fungi in the tribe Balansiae. Specific grass-endophytes have been implicated as the cause of toxicoses of grazing animals. For example, when animals graze tall fescue (Festuca arundinacea, Schreb) infected with Acremonium coenophialum Morgan-Jones and Gams, symptoms of fescue toxicosis or summer syndrome occur. Animals grazing endophyte-free cultivars (e.g., Johnstone, Kenhy, Au-triumph and Forager) show dramatic increases in average daily weight gains and improved rates of conception compared to animals grazing endophyte-infected tall fescue.

It is obvious that the alleviation of the symptoms of fescue toxicosis can be translated into large savings to the livestock producer. However, concern has been expressed that removing the fungal endophyte from tall fescue might result in the loss in stands of the grass (Siegel et al., 1987). In order to understand this potential loss, it is necessary to comprehend the unique relationship that exists between grass host and fungal endophyte.

CONCEPTS OF SYMBIOSIS

Many of the fungal endophytes in grasses do not produce or induce detrimental effects on their host. The fungi spend their entire life cycle within the plant, infecting regions of the plant (leaf sheaths, crowns, meristems and seed) that act as 'sinks' for plant nutrients. The seed-borne nature of the endophytes have resulted in their spread along with their host throughout the world. In the U.S., over 90% of the 34 million acres of tall fescue are infested, with a mean infection rate of 58% (Shelby and Dalrymple, 1987).

The biology, ecology and physiology of the host-fungus relationship has been adequately reviewed (Siegel et al., 1985,1987; Bacon and Siegel, 1988; Clay, 1986; Pottinger et al., 1985). Perhaps the most striking aspect of the host-endophyte interaction is the discovery that the relationship involves mutualistic symbiosis.

In discussing the concepts of symbiosis, one must be aware of the difference between parasitic and mutualistic symbionts (Table 1). According to Lewis (1973), mutualistic symbiosis is characterized by a lack of destruction of host cells, nutrient or chemical cycling between host and fungus, enhanced longevity of host and fungus cells, greater photosynthetic capacity of host cells and a tendency toward greater host specificity than seen in necrotrophic infections. These characteristics translate into benefits which then may become requirements for the continued existance for both grass host and fungus. It is now clear that the seed-borne Acremonium endophytes are obligate symbionts not capable of surviving outside their grass hosts, except under laboratory conditions. What is unclear is whether the host tall fescue plant will survive and flourish without its fungal symbiont component.

EVIDENCE FOR MUTUALISM

Resistance to Herbivores

Endophyte-infected Festuca and Lolium species of grasses show striking resistance to predation by insects and over-grazing by animals. The insects listed in Table 2 are considered to be either important pests or potential pests of grasses, or the grasses are used as reservoir hosts. Not on the list are insects that are not economically important, but have been used in bioassays to determine the presence of endophyte. These include the house cricket (Acheta domesticus), oat-birdcherry aphid (Rhopalosiphum padi) and milkweed bug (Oncopeltus faciatus).

In New Zealand, the Argentine stem weevil (combined with over-grazing by sheep) was responsible for the loss of non-infested (A. lolii) perennial ryegrass (Lolium perenne L.) paddocks. This is a clear example of the inability of a grass being unable to survive without the endophyte component. As yet, loss of endophyte-free tall fescue in the U.S. due to insect damage has not been reported.

Over-grazing, coupled with stresses (drought), seem more likely to affect endophyte-free cultivars of tall fescue. Considerable observational data (Boling, unpublished data) suggests that this has occurred. Reed and Camp (1986) have indicated that there is less forage available to cattle grazing low-endophyte-infested pastures in Texas than to cattle grazing highly infested pastures. In addition, after three years of grazing, two of the three non-infested blocks had lost 74-84% of their grass stands. It is not surprising that there is less forage available in non-infested pastures to grazing cattle. The animals are healthy and have increased ADG. Consequently, it would be expected they would consume more forage. Figure 1 illustrates the availability of endophyte-infected (EI) and endophyte-free (EF) herbage to animals during periods of plant growth. At usual producer stocking rates, it is nearly impossible to over-graze endophyte-infected tall fescue. On the other hand, depending on the stocking rate, culture and

---

[1]Departments of Plant Pathology, Agronomy and Entomology, respectively; University of Kentucky, Lexington, KY 40503

environment, it will be possible to over-graze endophyte-free tall fescue which will result in damage to the plants' psuedostems. Over-grazing also affects recovery and growth of the plant and possibly results in stand deterioration. While this effect is more likely to occur in areas where plant adaptability is marginal (i.e., western Texas, Oklahoma and the southern portions of Alabama, Louisiana, Mississippi and Georgia), it will occur in other areas when environment and plant culture are not conducive for grazing at specified stocking rates.

The chemicals most likely responsible for insect resistance and fescue toxicoses are listed in Table 3. It has been suggested (Bacon _et al._, 1986) that the ergot alkaloids in infected tall fescue are primarily responsible for animal toxicosis. There are 3 groups of substances (ergot, loline and peramine alkaloids) known to be toxic to various insects. In infected plants, the ergot and peramine alkaloids are made by the endophyte, while the loline alkaloids are thought to be synthesized by the grass.

Effect of Endophyte on Plant Growth and Development

There is contradictory data on whether plants infected with endophyte have enhanced plant growth. In New Zealand, _A. lolii_-infected perennial ryegrass yielded 38% more total dry matter, increased total leaf area, tiller number and growth of pseudostems and roots than non-infected clones of the grass (Latch _et al._, 1985). In the U.S., when Kenhy entries having 5-75% levels of infestation were managed for hay-pastureage (hay yield, aftermath yield, fall stand estimate and maturity at harvest) or seed production (seed yield, fall accumulated growth and fall stand estimate), no differences were reported between the low-endophyte-infected and high-endophyte-infected stands (Siegel _et al._, 1984).

There are no differences in forage quality (crude protein, neutral detergent fiber, acid detergent fiber, and digestibility) between endophyte-infected and noninfected tall fescue. When infected tall fescue was grown under controlled conditions, the plants had greater rates of photosynthesis and a higher increase in fresh weight; they produced more tillers during regrowth; and they had a lower percentage leaf roll (during a drying cycle) than did endophyte-free tall fescue (Table 4, L. P. Bush, personal communication). Infected plants also used water more efficiently than did noninfected plants. These differences would support the hypothesis that infected tall fescue plants have advantages over noninfected plants when grown during periods of environmental stress.

CONCLUSION

Current information concerning the relationship between endophyte and grass host and how this relates to survival of endophyte-free tall fescue and perennial ryegrass cultivars are summarized in Table 5. The data seems to indicate that while _A. coenophialum_-infected tall fescue causes fescue toxicoses, under certain circumstances, it also enhances the survival of the grass. Endophyte-free tall fescue enhances animal production but is susceptable to over-grazing and, coupled with adverse environment, will cause stand loss. However, over-grazing is a problem that can be controlled. Where, in the past, endophyte-infected tall fescue managed the grazing characteristic and stocking rate of the animals; the producer will now have to do this to ensure survival of the grass and a continued supply of forage.

Insect predation of endophyte-free tall fescue is a potential problem and as yet, in the U.S., one that has not occurred. As long as endophyte-free tall fescue is grown in its region of adaptability and grazing of animals is well managed, the primary potential for stand loss will be due to insect predation.

The production of improved endophyte-infected cultivars may prove to be as auspicious as the introduction of endophyte-free grasses if endophyte biotypes can be isolated (naturally occuring) or produced (genetically engineered) which do not synthesize chemicals toxic to animals. The modified endophyte(s) can be introduced into the plant by either maternal line selection or by artificial inoculation at the seedling stage. This presumes that the chemicals thought responsible for animal toxicoses (i.e., ergot alkaloids) are different from those toxic to insects (i.e., peramine and loline alkaloids) and that improved infected cultivars produce only the latter compounds. The desirability of having _Acremonium_ endophytes in turf grasses to provide protection from insect attack has already been recognized by grass breeders (Funk _et al._, 1985). However, it is immaterial whether the new infected turf grass cultivars produce chemicals toxic to animals.

Literature Cited

Bacon, C. W., and M. R. Siegel. 1988. The endophyte of tall fescue. J. Prod. Agric. (In press).

Bacon, C. W., P. C. Lyons, J. K. Porter, and J. D. Robbins. 1986. Ergot toxicity from endophyte-infected grasses: a review. Agron. J. 78:106-116.

Clay, K. 1986. Grass endophytes. _In_ Fokkema, J. and J. Van den Heuvel (eds). Microbiology of the Phyllosphere. pp. 188-204. Cambridge Press, Cambridge, England.

Funk, C. R., P. M. Halisky, S. Ahmad, and R. H. Hurley. 1985. How endophytes modify turfgrass performance and response to insect pests in turfgrass breeding and evaluation trials. Proc. 5th Int. Turf Res. Conf. Avignon. pp. 137-145. Versailles: INRA.

Latch, G. C. M., W. F. Hunt, and D. R. Musgrave. 1985. Endophytic fungi affect growth of perennial ryegrass. N. Z. J. Agric. Res. 28:165-168.

Lewis, D. H. 1973. Concepts in fungal nutrition and the origin of biotrophy. Biol. Rev. 48:261-278.

Pottinger, R. P., G. M. Barker, and R. A. Prestidge. 1985. A review of the relationships between endophytic fungi of grasses (Acremonium spp.) and Argentine stem weevil (Listronotus bonarienses Kuschel). Proc. 4th Australas. Conf. Grassl. Invert. Ecol. pp. 322-331. Lincoln Coll., Canterbury.

Read, J. C., and B. J. Camp. 1986. The effect of the fungal endophyte Acremonium coenophialum in tall fescue on animal performance, toxicity, and stand maintenance. Agron. J. 78:848-850.

Shelby, R. A., and L. W. Dalrymple. 1987. Incidence and distribution of the tall fescue endophyte in the United States. Plant Dis. (In press).

Siegel, M. R., G. C. M. Latch, and M. C. Johnson. 1985. Acremonium fungal endophytes of tall fescue and perennial ryegrass: significance and control. Plant Dis. 69:179-183.

Siegel, M. R., G. C. M. Latch, and M. C. Johnson. 1987. Fungal endophytes of grasses. Ann. Rev. Phytopathology 25:293-315. Ann. Revs., Inc., Palo Alto, CA.

Siegel, M. R., M. C. Johnson, D. R. Varney, W. C. Nesmith, R. C. Buckner, L. P. Bush, P. B. Burrus, II, T. A. Jones, and J. A. Boling. 1984. A fungal endophyte in tall fescue: incidence and dissemination. Phytopathology 74:932-937.

Table 1. Concepts of Symbiosis[a]

1. Chemoheterotrophs derive their carbon compounds from either non-living organic materials (as saprophytes) or from living tissue (as parasites).

2. The relationship of parasites with their hosts is that of a common life, a symbiosis.

3. Gradations of existence occur in the relationship between host and symbiont.

    a. Parasitic - that relationship which results in destruction or impairment of its host.

    b. Mutualistic - that relationship which mutually and permanently furthers and supports the host and symbiont.

[a] After Lewis (1973).

Table 2. Species of insects reported to be affected by endophyte-infected grasses

Insect	Grass[a]	Fungus
Crambus spp. (sod webworm)	PRG	A.l
Listronotus bonariensis (Argentine stem weevil)	PRG,TF	A.l,A.c
Sphenophorus parvulus (bluegrass billbug)	PRG	A.l
Spodoptera frugiperda (fall armyworm)	PRG,TF	A.l,A.c
Schizaphis graminum (greenbug aphid)	PRG,TF, HF,CF	A.l,A.c, E.t,E.t
Blissus leucopterus hirtus (chinch bug)	CF	E.t
Heteronychus arator (black beetle)	PRG	A.l
Chaetocnema pulicaria (corn flea beetle)	TF	A.c

[a] Abbreviations: PRG, perennial ryegrass; TF, tall fescue; HF, hard fescue (F. longifolia); CF, Chewings fescue (F. rubra subsp. commutata); A.l, A. lolii; A.c, A. coenophialum; E.t, Epichloe typhina.

Table 3. Biologically active compounds isolated from endophyte-infected tall fescue

Chemical	Amt. µg/gm	Toxicity
Ergot alkaloids	25	Insect and Mammalian
Ergovaline		
Ergosine		
Ergonine		
Chanoclavine		
Pyrrolizidine alkaloids	7,500	Insect
N-formyl loline		
N-acetyl loline		
Peramine alkaloids	3	Insect
Tetraenone sterol	ND	Mammalian

Table 4. Plant Growth, Photosynthesis and Water Use Efficiency of Infected and Non-Infected G1-307 Tall Fescue[a]

	Endophyte-free	Endophyte-infected
Tiller no.	39	59*
Shoot fresh wt g	17	24*
Daily Photosynthesis (PS)	2.65	3.27
Water use g	822	812
Daily net carbon g	1.35	1.75*
g H_2O per g daily PS	308	246*
g H_2O per g daily net C	609	464*

a 10 observations for 5 days; * indicates significant differences (P=0.05).

Table 5. Summary

1.) Grass-endophyte relationship is mutualistic.

2.) Benefits for the fungus: Persistance; Dissemination

3.) Benefits for the grass: Growth and persistance; Reduced herbivore feeding

4.) The removal of the endophyte from perennial ryegrass has been proven to be detremental to the the grass.

5.) The removal of the endophyte from tall fescue has the potential to be detremental to the grass.

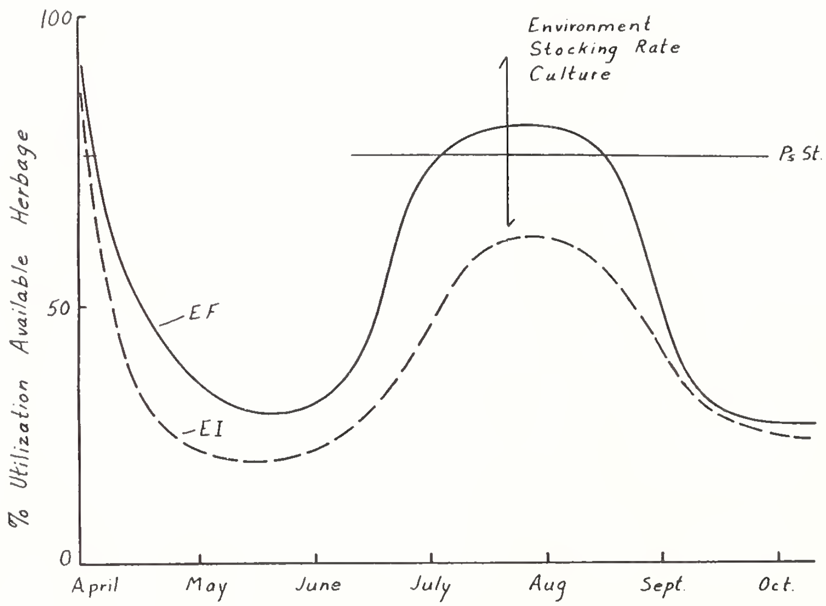

Figure 1. Utilization of available endophyte-free (EF) and endophyte-infected (EI) herbage to grazing animals from April through August. Ps St., plant psuedostems.

MANAGING THE PLANT-ANIMAL INTERFACE IN TROPICAL GRASS-LEGUME PASTURES[1]

W.F. Brown[2], J.E. Moore[3], and P. Mislevy[2]

The plant-animal interface as it relates to a grazing situation can be defined in terms of the interactions that exist when animals are in contact with forage plants (Moore and Sollenberger, 1986). This interface is dynamic, but can be broadly characterized into two areas. First is the animal defoliation effect from intake, trampling, feces, and urine on the pasture canopy both in the near and distant future; near future in terms of day-to-day changes, and distant future in terms of weeks primarily in rotationally grazed pastures. The second characteristic involves changing pasture canopy structure on animal ingestive behavior, diet composition, digestibility, intake, and animal performance.

Plant-animal interface research is demanding, and must be justified before an experiment is initiated. Characterization of canopy structure and animal ingestive behavior measurements are labor intensive, but must be completely investigated for a complete understanding of plant-animal interactions. However, this research provides quantitative measures of what people believe they have observed for many years. This research aids in developing and evaluating grazing management, and supports animal performance measures from grazing studies. However, results related to grazing management obtained from intensive plant-animal interface research conducted in small pastures, should be carried to the next phase of evaluation in terms of measuring animal performance.

GENERAL PROCEDURES

Canopy Measurements

Canopy measurements, to obtain true characterization of a pasture to which a treatment is applied can be more difficult to obtain than animal measurements. This is particularly true in grass-legume associations where there is differential growth between grass and legume, or differential animal preference for grass or legume. In addition, complex problems arise in sampling pastures which are not grazed uniformly, or where patterns of grazing are established. For example in the plant-animal interface experiment reported below, rotational grazing of stargrass (Cynodon nlemfuensis Vanderyst) - American jointvetch (Aeschynomene americana L.) pastures resulted in even defoliation of the pasture canopy. Therefore, canopy measurements made at five sites per 0.10 ha pasture were adequate to characterize these pastures. However, in another study (Morales et al., unpublished), patterns of grazing were established, particularly in continuously grazed bahiagrass (Paspalum notatum Flugge.) - aeschynomene pastures. In this case a double sampling technique was used. Canopy measurements at five sites per 0.05 ha pasture were physically obtained. These five sites were selected to represent the range in canopy structure that existed on a given sampling date. Visual observations of whole canopy herbage mass (kg/ha), and percentages of grass and legume were obtained at these five sites in addition to 30 additional sites within each pasture. Values at the 30 sites were adjusted based upon physical separation at the five sites.

Actual canopy measurements include canopy height, and physical separation of the canopy into 10 cm layers. In some cases each layer is separated, while in other cases the upper 2 to 3 layers are separated into proportions of: grass (leaf and stem), legume (leaf and stem), dead, and other fractions.

There are many options to expressing canopy data. Bulk density (kg/ha/cm) is useful in describing the distribution of canopy components in space, however can lead to misleading results in pastures that are not grazed uniformly, or where there is differential growth or animal preference for one canopy component over another. For example in postgraze sampling of a bahiagrass-aeschynomene association, an aeschynomene plant may be taller than a bahia plant, and all the leaf may be consumed from the aeschynomene plant. In this case, low bulk density of aeschynomene stem in the upper layer is not very meaningful. Canopy data, expressed as component composition within a layer is useful to describe not only changing canopy structure due to animal effects, but also to relate to animal ingestive behavior and diet composition measurements.

The animal component of the plant-animal interface is expressed in many ways. We use trained esophageally fistulated steers fitted with collection bags and electronic equipment to measure this component. Forbes and Beattie (1987) found no difference in ingestive behavior or diet composition between esophageally fistulated and non-fistulated animals. Ingestive behavior measurements we obtain include:

(a) rate of intake (bites per minute, BPM) - is measured with a hand tally counter by a trained technician. A bite is defined as the sound of forage being severed.

---

[1] This research was supported by the U.S Department of Agriculture under CSRS Special Grant No. 83-CRSR-2-2163 managed by the Caribbean Basin Advisory Group (CBAG).
[2] Animal Scientist and Agronomist, University of Florida, AREC-Ona, Rt. 1 Box 62, Ona, FL 33865
[3] Animal Science Department, University of Florida, Gainesville, FL 32611

Table 1. Bulk density (kg OM/ha/cm) of rotationally grazed stargrass pastures

	Pregraze				Midgraze				Postgraze			
Layer	Leaf	Stem	Green	Dead	Leaf	Stem	Green	Dead	Leaf	Stem	Green	Dead
40–50	20	7	27	2								
30–40	45	27	72	2	27	28	55	4	13	29	42	9
20–30			98	6	34	62	96	5	17	57	74	12
10–20			106	10			98	27			85	20
0–10			71	28			90	36			53	45

OM = organic matter; stargrass (Cynodon nlemfuensis, Vanderyst); Layer is cm from ground level.

Table 2. Bulk density (kg OM/ha/cm) of rotationally grazed stargrass-aeschynomene pastures

	Pregraze							Midgraze							Postgraze						
	Grass			Legume				Grass			Legume				Grass			Legume			
Layer	L	S	G	L	S	G	D	L	S	G	L	S	G	D	L	S	G	L	S	G	D
40–50	12	4	16	5	2	7	0														
30–40	24	13	37	7	5	12	0	21	20	41	5	0	5	0							
20–30			72					19	54	73	6	6	12	23	14	44	58	0	0	0	11
10–20			101							83			4	49	11	83	93	0	8	8	21
0–10			86							77			6	48			91			10	25

OM = organic matter; stargrass (Cynodon nlemfuensis, Vanderyst); aeschynomene (Aeschynomene americana)
L = leaf, S = stem, G = green, D = dead proportions.

(b) jaw movements (per minute, JPM) - is measured by a microswitch attached to an elastic band which fits around the steers nose, somewhat similar to that used by Chambers et al. (1981).

(c) bites per 100 jaw movements (B100JM) - is the ratio of BPM/JPM*100. This indicates the amount of forage manipulation occurring during prehension.

(d) bite weight (BSIZE) - is obtained by total recovery of the extrusa during the sampling period, divided by the number of bites.

(e) intake per minute (IPM) - is BPM * BSIZE. Under some conditions, a grazing treatment resulting in greater BPM can have a lower BSIZE, however IPM can be greater than a grazing treatment resulting in fewer BPM but larger BSIZE.

In addition to ingestive behavior measurements, botanical and plant part composition of esophageal extrusa samples are determined using a double sampling technique involving hand separation and microscopic analysis. Under best cases we hope to measure grass leaf and stem, legume leaf and stem, dead, and other components.

CANOPY CHARACTERISTICS, INGESTIVE BEHAVIOR, AND DIET COMPOSITION OF STEERS GRAZING TROPICAL GRASS VS. TROPICAL GRASS-LEGUME PASTURES

In 1985, canopy characteristics, ingestive behavior and diet composition of steers rotationally grazing stargrass vs stragrass-aeschynomene pastures were evaluated. After a 4 week regrowth period, pastures were sampled and ingestive behavior measurements were obtained at pre- (day 1), mid- (day 7), and post- (day 14) grazing times. Grass pastures received supplemental nitrogen (45 kg/ha), while grass-legume pastures did not.

Canopy Characteristics

Pregraze stargrass pastures were characterized by lower density upper and lower layers, with most of the density located in the middle layers (Table 1). The upper layer at pregraze sampling was removed by midpoint grazing, and what became the upper layers were more dense and composed of greater proportions of stem and dead material. At postgraze sampling, upper layers became less dense primarily due to animal selection for leaf material, and there was increased accumulation of dead material in lower layers.

Aeschynomene is a good choice to grow in association with stargrass, because the greatest legume density is located in the upper layers, making the upper layers of this association more dense with desirable components, namely grass leaf and legume leaf (Table 2). By midgrazing, the upper layer was removed, and as in grass alone pastures, upper layers were more dense and composed of increased proportion of grass stem and reduced legume concentration. By the time of postgraze sampling, the new upper layers were more dense with greater proportions of stem and dead material. Only small amounts of aeschynomene were present in the pastures at postgraze sampling.

Component composition for the upper two layers of rotationally grazed stargrass pastures are presented in Table 3. In pregraze sampling, the upper two layers were composed primarily of leaf, with less stem material. The top layer had greater proportions leaf, and less stem than

Table 3. Component composition (%) within the top two layers of rotationally grazed stargrass pastures

	Pregraze				Midgraze				Postgraze			
Layer	Leaf	Stem	Green	Dead	Leaf	Stem	Green	Dead	Leaf	Stem	Green	Dead
Top 1	70	25	95	5	45	48	93	7	25	58	83	17
Top 2	61	36	98	2	34	61	95	5	20	66	86	14

Table 4. Component composition (%) within the top two layers of rotationally grazed stargrass-aeschynomene pastures

	Pregraze							Midgraze							Postgraze						
	Grass			Legume				Grass			Legume				Grass			Legume			
Layer	L	S	G	L	S	G	D	L	S	G	L	S	G	D	L	S	G	L	S	G	D
Top 1	52	17	70	22	9	30	0	46	43	89	11	0	11	0	20	64	84	0	0	0	16
Top 2	49	28	77	14	10	24	0	18	50	68	6	6	12	21	9	68	76	0	7	7	17

L = leaf, S = stem, G = green, D = dead proportions (%).

Table 5. Ingestive behavior of steers grazing stargrass and stargrass-aeschynomene pastures

	Period			P	
	Pre	Mid	Post	PTYPE	PERIOD
Bite rate (/min)					
grass	38	24	21	0.09	L 0.01
grass + legume	44	27	24		Q 0.01
Jaw movements (/min)					
grass	74	70	73	0.96	0.13
grass + legume	77	71	70		
Bites/100 jaw movements					
grass	51	35	29	0.10	L 0.01
grass + legume	56	41	35		Q 0.08
Bite weight (g OM)					
grass	1.1	.9	.8	0.04	L 0.01
grass + legume	.9	.5	.6		Q 0.05
Intake/min (g OM)					
grass	40	22	16	0.02	L 0.01
grass + legume	38	14	14		Q 0.01
Extrusa GL (%)					
grass	84	57	18	0.01	L 0.01
grass + legume	50	50	24	inter	L,Q 0.01
Extrusa GS (%)					
grass	13	38	68	0.20	L 0.01
grass + legume	6	44	61		
Extrusa LL (%)	40	2	1		Q 0.01
Extrusa LS (%)	3	1	1		0.37
Extrusa dead (%)					
grass	3	5	14		
grass + legume	0	3	14	0.33	L 0.01

P = probability for pasture type (PTYPE) and grazing period (PERIOD); OM = organic matter; Extrusa = diet collected from esophageally fistulated steers; CP = crude protein; GL = grass leaf; GS = grass stem; LL = legume leaf; LS = legume stem.

the layer below it. Proportions of leaf decreased, while proportions of stem increased from pre- to midgrazing, with a slight increase in dead material. Leaf proportion of the upper layers continued to decline, and stem proportion increased from mid- to postgraze, with further increases in dead material.

In pregraze stargrass-aeschynomene pastures, upper layers were composed of approximately 70% grass and 30% legume, with grass leaf making up most of the grass portion, and legume leaf making up most of the legume portion (Table 4). At midgrazing, grass leaf proportion of the upper layers decreased, while grass stem proportion increased to a greater degree. Legume proportion, particularly legume leaf declined from pre- to midgrazing. As in grass pastures, grass leaf proportion declined while grass stem proportion increased from mid- to postgrazing. Only small amounts of legume remained in the canopy at postgrazing, and dead material accumulated.

Ingestive Behavior And Diet Composition

At pregraze sampling, when canopy characteristics were desirable, namely grass leaf and legume leaf in the upper layers, biting rate by cattle was greatest, and declined in a quadratic manner to postgrazing (Table 5). Jamieson and Hodgson (1979) obtained reduced biting rate as herbage allowance per animal was reduced. Biting rate tended to be greater in grass-legume compared to grass pastures. Generally, differences between pre- and midpoint grazing, for most ingestive behavior and diet composition measurements, were greater than differences between mid- and postgrazing. Consistent with other results (Moore and Sollenberger, 1986), total jaw movements were not affected by grazing period or pasture type. Bites per 100 jaw movements followed the same trend as biting rate. Less manipulation of forage occurred prior to consumption in pre- compared to mid- and postgrazing, and cattle tended to manipulate forage less in grass-legume compared to grass pastures.

Cattle grazing grass pastures had a slower bite rate, but larger bite weight compared to cattle grazing grass-legume pastures, which had a faster bite rate but smaller bite weight (Table 5). The combination of biting rate and bite weight resulted in cattle grazing grass pastures consuming more forage per minute, compared to cattle grazing grass-legume pastures. Bite weight and intake per minute declined in a quadratic manner from pre- to postgrazing. Chacon et al. (1976), Jamieson and Hodgson (1979), and Kanyama-Phiri and Conrad (1986) found reduced biting rate, bite weight, and rate of intake in post- compared to pregraze sampling.

An interaction existed between pasture type and grazing period for dietary grass leaf (GL) content (Table 5). During pregrazing, dietary GL from grass-legume pastures was lower than that from grass pastures, due to 14-22% legume leaf (LL) in the upper layers of grass-legume pastures (Table 4) leading to 40% LL in the diet of steers grazing these pastures. Upper layers of grass-legume pastures contained approximately 50% GL, indicating that cattle grazing these pastures had no positive selection for GL. However, upper layers of grass pastures contained approximately 65% GL, while dietary GL of steers grazing these pastures was 84%. For both pasture types, GL content of the diet was greater than that of the canopy at midgrazing, however, at postgrazing dietary GL content was similar to that found in the canopy.

Dietary grass stem (GS) content increased in a linear manner over time, with no difference between pasture types (Table 5). Dietary GS was less than that in the upper layers of both pasture types at pre- and midgrazing, however similar to that in the upper layers at postgrazing.

Legume leaf content of the diet of steers grazing grass-legume pastures during the pregraze sampling was 40%, while the upper layers of these pastures contained 14-22% LL. Even though the upper layers of grass-legume pastures contained 6-11% LL during midgrazing, only 2% LL was found in the diet. Only small amounts of LL were found in grass-legume pastures and in the diet during postgrazing.

Chacon et al. (1978) found that spatial distribution of plant part components within the canopy greatly influenced growth of steers. In their study, cattle were sometimes unable to satisfy their feed requirements on high quality but low yielding pastures despite increased grazing time to compensate for small bites prehended. This is consistent with our data and supports the suggestion that for grasses such as stargrass, where canopy structure is altered by grazing in terms of leaf and stem composition of the upper layers, performance of cattle with high nutrient requirements may be limited by canopy structure and composition at a point where significant quantities of forage exist. For example, in postgraze stargrass pastures, dietary GL content was similar to or less than GL content of the canopy even though total herbage mass was approximately 3000 kg/ha and canopy height was 35 cm (Tables 3 and 5). In addition, midgraze sampling of grass-legume pastures resulted in 6-11% LL in the upper layers, however only 2% LL in the diet of cattle grazing these pastures (Tables 4 and 5). This could have been due to low bulk density of grass leaf and legume leaf in the upper layers, and cattle were not physically able to consume these components without consuming greater proportions of other canopy components present in greater quantities. This has application in a lead-follow grazing management system, where cattle with high nutrient requirements such as growing calves could remove the upper layers of a pasture until ingestive behavior characteristics limit performance, at which time they would be moved to a new pasture. They would be replaced by a group of cattle with lower nutrient requirements such as gestating cows which would remain until a desired quantity of forage was removed.

Literature Cited

Chacon, E., T.H. Stobbs, and R.L. Sandland. 1976. Estimation of herbage consumption by grazing cattle using measurements of eating behaviour. J. Brit. Grassl. Soc. 31:81.

Chacon, E.A., T.H. Stobbs, and M.B. Dale. 1978. Influence of sward characteristics on grazing behaviour and growth of Hereford steers grazing tropical grass pastures. Aust. J. Agric. Res. 29:89.

Chambers, A.R.M., J. Hodgson, and J.A. Milne. 1981. The development and use of equipment for the automatic recording of ingestive behaviour in sheep and cattle. Grass Forage Sci. 36:97.

Forbes, T.D.A., and M.M. Beattie. 1987. Comparative studies of ingestive behaviour and diet composition in oesophageal-fistulated and non-fistulated cows and sheep. Grass Forage Sci. 42:79.

Jamieson, W.S., and J. Hodgson. 1979. The effect of daily herbage allowance and sward characteristics upon the ingestive behaviour and herbage intake of calves under strip-grazing management. Grass Forage Sci. 34:261

Kanyama-Phiri, G., and B.E. Conrad. 1986. Effects of stocking rate on forage-on-offer bite rate, bite size, bite quality, and animal weight gain on warm season pastures. Forage Research in Texas. pp. 41.

Moore, J.E., and L.E. Sollenberger. 1986. Canopy structure effects on ingestive behavior. Proc Southern Pasture Forage Crop Improvement Conf. Athens, GA. pp 53.

TECHNIQUE CONSIDERATIONS IN GRAZING MANAGEMENT RESEARCH

A.G. MATCHES[1]

A number of good publications on forage evaluation are available and I recommend them for your bookshelf. They include the following: Briske and Kothmann, 1982; Campbell, 1969; Cook and Stubbendieck, 1986; Hodgson et al., 1981; Leaver, 1982; 't Mannetje, 1978; and Wheeler and Mochrie, 1982.

In preparation, I reviewed 78 grazing experiments which have been published in the Journal of Animal Science and the Agronomy Journal over the past 13 to 15 years. Each experiment was rated on research techniques used and completeness of data reported. Overall, 50% scored good to excellent, 30% fair, and 20% poor. Shortcomings noted plus technique considerations which are often neglected form the basis of my presentation.

TWO BIOLOGICAL SYSTEMS

The consequence of interfacing two biological systems (plant and animal) must remain paramount in the researcher's mind. Factors influencing either system will ultimately influence output per animal and pasture yield (animal products, feed units, dry matter, etc.). Especially important is the relationship of declining animal gain as stocking rate or grazing pressure is increased, but maximum gain per hectare usually occurs at a point beyond maximum average daily gain per animal. Disregarding this relationship in grazing management research will yield erroneous results.

FIXED OR VARIABLE RATE STOCKING

Opinions differ among researchers on whether a fixed or a variable (put-and-take) rate of stocking should be used in grazing trials. Wheeler et al. (1973) reviewed this subject and have suggested situations where each method seems appropriate. In general, I prefer a variable stocking rate when characterizing untested forages or treatments for potential output per animal, pasture carrying capacity, and animal production per ha. Fixed stocking rates are appropriate for comparisons with a "standard", and in "pasture-system trials" which include two or more pasture components. With pasture systems, feed supply may be regulated by timing the grazing of each component pasture.

1/ Department of Plant and Soil Science, Texas Tech University, Lubbock, TX 79409.

MULTIPLE STOCKING RATES

Forages and animals may respond differently to intensities of stocking (Bransby, 1981); therefore multiple stocking rates should be considered in many grazing-management investigations. At least three stocking rates should be compared. Where research resources are limiting, Riewe (1961, 1965) has proposed substituting pasture replications with four or more rates of stocking; analysis of covariance techniques are then used to describe animal gain responses to the various forage-stocking rate combinations. This technique offers opportunities particularly in the early evaluations of potential components of future pasture systems. Obtaining measurements of herbage availability throughout the grazing season is desirable for comparing results on both a grazing pressure and stocking rate basis. Because of a lack of formal pasture replication, some scientific journals may be reluctant to accept research findings for publication.

SWARD MEASUREMENTS

Detailed sward measurements are essential for the complete interpretation of grazing results. They are useful for: 1) explaining differences in animal response; 2) modeling of animal response; 3) describing animal and treatment effects on the sward; 4) describing herbage allowance, residue, percent utilization, and dry matter production trends, 5) describing animal preference and selective grazing; 6) estimating intake and 7) comparison of results among years, locations and researchers. Unfortunately, many published grazing trials have failed to report enough information about the sward.

EXPERIMENTAL ERRORS

Expected size of experimental errors in grazing trials may be estimated with the equations of Petersen and Lucas (1960). Their equations are very helpful in selecting pasture size, number of animals and expected days of grazing based upon the magnitude of experimental errors the researcher is willing to accept. We found our estimated and actual experimental errors to be quite similar in small pasture evaluations of tall fescue cultivars (Matches et al., 1983). Readers are encouraged to use the Petersen and Lucas equations in designing new grazing-management trials.

When cattle for a given treatment are rotated from pasture replication to replication to achieve rotational grazing, the accumulation of weighing errors may inflate error terms and thus decrease the chances of detecting significant differences among treatments. This may be avoided by subdividing pastures within a replication for rotational grazing (Mott, 1959).

Likewise, when years are used as replications, year by treatment interaction may also inflate the error term in the analysis of variance.

CONCLUSIONS

It is unlikely that all research goals and objectives can be effectively accomplished in a single experiment. Therefore, carefully define your objectives, rank your objectives, and then proceed accordingly.

Literature cited

Bransby, D.I. 1981. The effect of herbage availability on animal performance off Kikuyu and Coastcross II. Proc.. Grassld. Soc. Sth. Afr. 16:49-60.

Briske, David D. and M.M. Kothmann. (Eds.). 1982. Proc. of a National Conf. on Grazing Management Technology. Texas A&M University.

Campbell, J. Baden. 1969. Experimental methods for evaluating herbage. Canada Dept. of Agric. Pub. 1315. Queen's Printer, Ottawa.

Cook, C. Wayne and James Stubbendieck (Eds.). 1986. Range research: Basic problems and techniques. Soc. Range Mgt., Denver, CO.

Hodgson, J., R.D. Gaker, Alison Davies, A.S. Laidlow, and J.D. Leaver. (Eds.). 1981. Sward measurement handbook. Brit. Grassld. Soc., Grassld. Res. Inst., Hurley, Maidenhead, Berkshire, England.

Leaver, J.D. (Ed.). 1982. Herbage intake handbook. Brit. Grassld. Soc., Grassld. Res. Inst., Hurley, Maidenhead, Berkshire, England.

Matches, A.G. 1970. Pasture research methods. In. R.F. Barnes, D.C. Clanton, G.H. Gordon, T.J. Klopfenstein, and D. Waldo (Eds.). Proc. Nat. Conf. on Forage Quality Evaluation and Utilization. Neb. Ctr. for Continuing Education. Lincoln, NE. I--1-33.

Matches, A.G., F.A. Martz, D.A. Sleper, and R.L. Belyea. 1983. Grazing techniques for evaluating quality of forage cultivars in small pastures. In J.A. Smith and V.W. Hays (Eds.). Proc. 14th Int. Grassld. Cong. Lexington, KY. 514-516.

Matches, A.G. and G.O. Mott. 1975. Estimating the parameters associated with grazing systems. In R.L. Reid (Ed.). Proc. 3rd World Conf. on Animal Prod. Sydney, Aust. 203-208.

Mott, G.O. 1959. Intersociety forage evaluation symposium: III. Animal variation and measurements of forage quality. Agron. J. 51:223-226.

Petersen, R.G. and H.L. Lucas. 1960. Experimental errors in grazing trials. Proc. 8th Int. Grassld. Cong. Univ. of Reading, England. 747-750.

Riewe, M.E. 1961. Use of the relationship of stocking rate to gain of cattle in an experimental design for grazing trials. Agron. J. 53:309-313.

Riewe, M.E. 1965. An experimental design for grazing trials using the relationship of stocking rate to animal gain. Proc. 9th Int. Grassld. Cong. Sao Paulo, Brazil. 1507-1510.

'tMannetje, L. (Ed.). 1978. Measurements of grassland vegetation and animal production. Commonwealth Bureau of Pastures and Field Crops. Hurley Berkshire, England. Bull. 52.

Wheeler, J.L. and R.D. Mochrie. (Eds.). 1981. Forage evaluation: concepts and techniques. Am. Forage & Grassld. Council and CSIRO. Griffin Press Ltd., Netley, Aust.

INTENSIVE GRAZING MANAGEMENT

J. P. Mueller[1], J. T. Green[1]

Developing a Grassland Philosophy

Ruminant animals are the primary consumers of forage plants. In the USA, the primary ruminants are cattle. In the early days of this country, meat and milk were produced on native grasslands with little active grassland management by cattlemen. As western native grassland became available for grazing, beef cattle production expanded rapidly on the open range. This was an extensive system of production based entirely on the natural productivity of the range. There was no need for a sound grassland philosophy. Grass was plentiful, land was cheap and thus the range was exploited without regard to subsistance of the plant communities.

Since World War II, ruminant animal production in the US has thrived because large surpluses of high energy feed grains have resulted in a cheap feed source effective in improving feed conversion efficiency. Nevertheless, beef and dairy farmers were diverted from developing grassland management skills and a basic grassland philosophy that are needed today. During the post war period, millions of cattle were moved from pastures to drylot in order to take advantage of the boost in production achieved through feeding cheap, high energy grains.

The substitution of grain for forage (primarily pasture) provided an alternative production system which avoided many of the difficulties of producing beef and milk on pasture. No longer were cattlemen faced with seasonal ups and downs associated with pasture production systems. Rates of gain and milk production were increased drastically. Feed could be maintained at a consistent level of quality and could be accurately allocated to the animals on a daily basis. Huge grain surpluses and abundant, cheap fossil fuels have sustained and intensified the drylot system associated with heavy grain feeding because it has remained profitable to do so. To present day, this production system has tended to expand rather then shrink. As a result, many of the relevant problems facing grassland managers were averted and never effectively solved through scientifically sound grassland management. Much of our system of producing meat and milk is oriented toward using surplus feed grains, not efficient grassland management.

The orientation toward feed grains has tended to over emphasize the importance of production of beef and milk on a per head basis with a concurrent deemphasis of production per farm unit or land area devoted to such production. This philosophy detracts from the notion that land is the basic unit of production. It has relevance only when land is very cheap (cheaper than the animals produced on it) or in the cases of the milk or meat 'factory' where no land is available for feed production. In this case, all feed (the raw materials) are purchased and used to manufacture the product (beef or milk).

During the past fifty or so years, a subtle change has taken place in the beef cattle industry. A substantial proportion of the cow herds shifted eastward so that at present about 50 percent of the nation's beef cows reside in the Southern region. The humid Southeastern United States is characterized by a moderate climate consistent with an extended grazing season, much rough erodible land not suited to row crop production and a close proximity to major population centers and urban areas. Even with this situation which is highly conducive to intensive grassland management, few farmers have developed the necessary pasture management expertise in practical farm situations.

Before the full potential of pasture can be realized in the region, farmers need to accept a positive grassland philosophy based on an efficient and profitable system of management.

The current economic conditions for farming have generated interest in reducing input costs as a means of increasing net profit. Many beef and dairy producers are beginning to consider intensive pasture management in this regard. It is time to develop a positive grassland philosophy that is integrated with, and relevant to the availability of cheap supplemental feed, but not totally dependent on such feed for economic returns.

An Introduction to Controlled Grazing

What is "Controlled Grazing"?

Simply stated, "Controlled Grazing" management aims to regulate the frequency and intensity of grazing to control quality, yield, persistence, and intake of pasture. Pasture management is regulated by plant growth rate and stage of maturity. "Controlled Grazing" adjusts the amount of pasture eaten to seasonal growth in an attempt to optimize animal performance and minimize wasted forage.

The area of fresh pasture alloted to a given number of animals (stock density) is varied by the manager so that he can control the amount of forage eaten, its quality and how long each pasture is rested between grazings. In this way, the manager has the ability to manipulate pasture growth to satisfy animal requirements.

"Controlled Grazing" is the central feature of a 12 month forage system based on optimum use of grazed forage. The best 12 month forage system usually involves several plant species or mixtures of species with different seasonal production capabilities. The adoption of this concept will require a change in the way most farmers view the importance of pasture

[1]Department of Crop Science, N.C. State University, Raleigh, N.C. 27695-7620

management. "Controlled Grazing" places a high priority on pasture management activities and views pasture land as a valuable resource not to be wasted.

Grazing Management Systems: Continuous, Rotational, Controlled

The traditional "system" of grazing in the region has been to construct a fence around a community of plants (mainly grasses), introduce a group of animals and wait to see what happens. In most cases, the area is stocked so that catastrophic weight loss is not experienced during periods of the year when pasture growth is slow or absent. This means that cool-season pastures are understocked during flush spring growth and slightly to grossly overstocked during the slowest growth periods (summer and winter).

Continuous grazing, as traditionally practiced, is management defaulted from man to animal. It has been widely practiced because no particular management skill is required, and because reasonable levels of live weight gains are attained during periods of good growth. However, gain per acre is usually far below the potential maximum. It is true that year around continuous grazing is simple to implement and requires no grazing management effort, but the ability of the manager to manipulate the system for maximum profit is lost.

Rotational grazing is the practice of imposing a regular sequence of grazing and rest from grazing upon a series of pastures. For example, each paddock in a system is grazed for 10 days and rested for 25 days; this management is continued for all or most of the year.

The controlled grazing concept uses both continuous and rotational grazing management in a flexible system that can cope with changes in pasture quantity and quality (according to animal requirements). Unlike strict rotational grazing, rest periods, grazing periods, and grazing cycles are never rigidly fixed for extended periods. Unlike traditional continuous grazing, the grazing is never continuous year around. For example, cool-season species (such as fescue-clover) may be continuously grazed for 40 to 60 days during flush spring growth when pasture quality and quantity are high and animals have potential for rapid live weight gains. When too much forage begins to accumulate resulting in a reduction in quality, certain paddocks can be "shut down" for hay or silage harvest. Animals can then be regrouped for rotational grazing on the remaining paddocks using the appropriate grazing cycle based on plant growth and animal needs. The following "steps" are practical suggestions that farmers should consider when attempting to implement a "Controlled Grazing" management program.

Seven Steps to Controlled Grazing Management

1. Develop a plan -- including goals that are both possible and profitable.
2. Select the best adapted grass and/or legumes -- that are most productive, and most persistent for your soils and climate. Both cool and warm season pasture species will be needed to provide the best 12 month forage system. Include a legume if it is profitable. Usually better animal performance at reduced cost can be expected when a legume (such as ladino clover) can be maintained in the pasture sward.
3. Lime and fertilize pasture -- based on soil test recommendations.
4. Subdivide pastures -- so that 6-15 separate paddocks can be made available. The optimum number of paddocks on a farm is debatable, but most farmers who have practiced controlled grazing tend to increase rather than decrease the original number of paddocks. High tensile power fence is generally the cheapest, most effective form of subdivision. Additional paddocks can be easily obtained by further subdivision of the base paddocks using temporary electric polywire or polytape.

Design pasture fencing in order to separate:
a. hill land from bottom land
b. shady slopes from sunny slopes
c. areas of differing plant types, i.e., endophyte infested fescue from "clean" fescue.
d. shallow, droughty soils from deep, productive soils.

5. Learn to estimate the yield -- of green pasture dry matter (lbs/A) (both before and after grazing). The first step is to use pasture height as a guide. For fescue/fescue clover, this would mean grazing from 6-8 inches back to 2-4 inches for most of the year.

Both height and density of pasture are important when accessing pasture yields. Assuming a reasonable degree of density, some very rough "rules of thumb" follow:

Species	Pasture Canopy Height (inches)			
	2	4	6	8
	------DM yield lbs/a[1]---			
Fescue-clover	700	1500	2000	2400
Hybrid Bermuda[2]	1000	2000	2500	3000
Rye (small grain)	300	700	1300	1700

[1]N.C. State University estimates - these values are based on DM cut to ground level.

[2]the quality of bermuda declines rapidly after it reaches 4" tall.

6. Manage for high proportion of green leaf -- avoid grazing dead matter and rank stems with seed heads with animals that have high nutrient requirements. Clip pastures only when the forage cannot be grazed. If paddocks ahead in

the rotation begin to accumulate growth in excess of 8 inches, they should be taken out of the rotation and harvested as hay (at boot stage or after 25-30 days regrowth). In winter, when cool season grass growth ceases, autumn accumulated growth should be rationed out using temporary electric wire and supplemental feed offered as necessary.

7. Adjust grazing frequency to the rate of pasture growth -- and/or desired animal performance. Lengthen the grazing cycle, increase stock density and the grazing period when pasture growth is slow or animal requirements are low or when building up stockpiled growth for winter. Shorten the grazing cycle, decrease stock density and the grazing period when pasture growth exceeds animal needs or when high per head animal production is required.

Definition of terms:

Grazing period -- Length of time for which a particular area of land (paddock) is grazed.

Grazing cycle -- The length of time (days) between the beginning of one grazing period and the beginning of the next on a particular area of land (paddock).

Stock density -- The number of animals of a specific class per unit area of land actually being grazed at a point of time. If 10, 700 lb steers are grazing a one-acre paddock, the stock density is 10 steers/acre/day.

NATIONAL ALFALFA SYMPOSIUM

Garry D. Lacefield & Troy Johnson*

The 17th National Alfalfa Symposium "Alfalfa in the South" was held March 17 in Atlanta, Georgia. The Symposium was attended by approximately 290 people from 29 states. The number of states represented set a new record for the symposium and the attendance was about a third over last year.

Fourteen speakers from throughout the southeast addressed the theme "Alfalfa in the South - Turning Potential into Profit." A highlight of the day was a producer forum which featured four producers from Virginia, Florida, Georgia and Tennessee addressing the topic of "Alfalfa in My Farming Operation."

This National Alfalfa Symposium marked the first to be held in the south and the first to be put together and implemented on a regional basis. The program committee and the Certified Alfalfa Seed Council were most pleased with the attendance, participation and enthusiasm.

In addition to the program, participants had the opportunity to visit exhibits the evening before and during breaks throughout the day. Fifteen exhibitors had displays at the symposium. All registrants received proceedings and a complimentary copy of all publications produced by the Certified Alfalfa Seed Council.

Also featured at the Symposium luncheon was a premiere showing of the Certified Alfalfa Seed Council's new slide-tape presentation on "Alfalfa in the South." This slide-tape set will soon be available from the CASC.

A 63 page proceedings featuring the fourteen presentations at the symposium are available for $5.00 from the Certified Alfalfa Seed Council, Inc., P. O. Box 1017, Davis, California 95617-1017.

*Extension Agronomist, University of Kentucky and University of Georgia, respectively

Presented at Southern Pasture and Forage Crop Improvement Conference, Clemson, S. C., April 1987.

COOPERATIVE REGIONAL FORAGE VARIETY TESTING USING REGIONS OF APPLICABILITY

W.C. Stringer and D.J. Smith
Clemson University

Introduction:

Performance testing of forage cultivars can be a large and demanding task. Many different forage species are adapted and useful in the Southern U.S., including legumes and grasses, cool and warm season forages, and annuals vs. perennials. Each species has several to many cultivars available, with differing productivity and adaptive characteristics. The multiple-cutting production schedules of most forages complicate variety testing further, especially when grown at several locations.

Much of the value of a testing program arises from knowledge of the area of applicability of the results from a given test location. The fact that applicability of results many times crosses state lines suggests the possibility of interstate cooperation to share the work load of a thorough cultivar testing program. Table 1 gives a partial listing of current cultivar testing activity in the Southern region.

Procedures:

A region of applicability is defined as a region of similar soils characteristics, in particular, plant-available soil moisture capacity, and similar climatic conditions. Important climatic variables are: Total annual rainfall and seasonal distribution, length of frost-free growing season, and seasonal average temperatures.

For a first approximation at delineating regions of applicability, we examined climatic data from 19 weather stations in Georgia and 16 in South Carolina. Weather data were plotted by month using Lotus 123 graphics (see rainfall histogram examples in Fig. 1). Plots of significant weather variables for the various stations were placed in regions with similar characteristics, by visual examination. The soil and climatic pattern data for the weather stations were organized into a database using the DBASE II software on a personal computer. Simple sorting by important variables facilitated grouping of weather station locations with similar soil and climate into regions of presumed similar productivity.

Results and discussions:

The first sort of weather station locations was by soil association regions, which correspond closely with physiographic provinces. The physiographic province names were used to designate the regions: Mountains, Limestone Valley, Piedmont, Sandhills, Upper Coastal Plain and Lower Coastal Plain.

Mountain: Three weather stations were studied in this region, one in SC and two in GA. All three show similar rainfall histograms with uniform distribution (Fig. 1a). Total rainfall

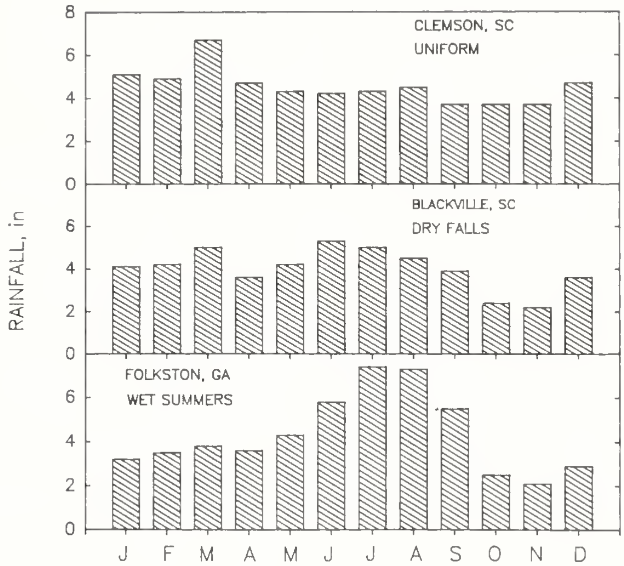

Fig. 1. Rainfall distribution at Clemson SC, Blackville SC, and Folkston GA

ranged from 126 to 185 cm. The total frost-free period ranged from 179 to 203 days. This region could probably be adequately serviced by the Georgia Mountain Station at Blairsville.

Piedmont: Nine weather stations were located in this region, four in SC and five in GA. Most of the stations showed a uniform rainfall pattern similar to Fig. 1a with a range of 117 to 137 cm. Two stations located on the southeastern margins of the Piedmont showed seasonal rainfall distributions more like the Upper Coastal Plain, with a dry fall season (Fig. 1b). The frost-free growing season ranged from 205 to 227 days. This region is well represented with testing stations, with Clemson, SC, and Athens, Experiment, Watkinsville and Eatonton, GA. Due to difference in seasonal rainfall, there is sufficient reason to break this area into two regions of applicability, an upper and a lower Piedmont. Eatonton and Experiment, GA would probably best serve the lower Piedmont.

Sandhills: All three weather stations for this region fell in SC. Monthly rainfall patterns reveal relatively uniform rainfall except for dry falls, with amounts ranging from 117 to 125 cm, and a frost-free growing season from 207 to 226 days. The mainly deep sandy soils of this area set it apart from Coastal Plains regions. The station at Pontiac, SC could probably serve most of this region.

Upper Coastal Plain: Seven weather stations in this region were in GA with four in SC. Soils in this region are mainly sandy at the surface with sandy clay subsoils. Rainfall histograms across this region reveal moderate monthly rainfall, with dry autumns. Rainfall amounts ranged from 112 to 137 cm. Frost-free growing seasons ranged from 214 days at the

northern margin to 254 days in the deep south of GA. This region is well covered with testing stations, with the Florence and Blackville stations in SC and Midville, Tifton and Plains in GA. Considerable opportunity for overlap should exist between the Edisto and Midville stations in supplying the information needs for most of this region.

Lower Coastal Plain: This region comprises the sandy but less well-drained soils along the coast. Three weather stations in SC and two in GA were located in this province. The rainfall patterns throughout this region are characterized by high summer rainfall. The rainfall amounts ranged from 122 to 132 cm. The area is characterized by long frost-free growing seasons, from 219 to 255 days. There are no test stations in this region although the station at Florence, SC is on the very margin, and the Tifton, GA station is close. It is possible that stations in northern Florida perhaps Gainesville could serve this region as well.

In summary, one or more existing test stations (USDA or Experiment Station) lie within the bounds of most of the soil association regions of GA and SC. Climatic data suggests significant regional overlap exists across states within the soil classification regions, such that cooperative arrangements to share variety test duties among states could be workable. A more thorough analysis of climatic data, as well as soils resources at test stations, is needed. A rigorously derived protocol would need to be developed, including placing standard cultivars at each station within a region. If this were done, it should be possible to share the load of testing forage cultivars among locations and states, and provide high quality producer information.

Table 1. Forage Cultivar Testing by Forage Type and State.

	State												
Forage Type	AL	AR	FL	GA	KY	LA	NC	OK	SC	TN	TX	VA	MS
	Numbers of locations												
Cool-season perennial grasses	5	3	2	4	2		3		2		3	4	5
Warm-season perennial grasses	2	2		1			3		3		2		8
Clovers, annual legumes	4	2	4	2	2		3		3		7		7
Alfalfa	3	2	1	4	2		4	6	2		6	3	5
Tall warm season perennial grasses		2					4		3			2	3
Small Grains	9		1			7	3	5	1		4		8
Ryegrasses	6	2	3			8	3				1		8
Warm season annuals		2	2	2		3					3		5
Warm season legumes mostly sericea	2						1						

BUSINESS MEETING AND RELATED MATTERS

MINUTES OF THE 43rd SPFCIC MEETING

Time: April 21, 1987
Clemson, South Carolina

Dr. Hagen Lipke, Chairman, called the meeting to order. The business began with a roll-call of states.

OLD BUSINESS

Item 1: A financial report was made by J.T. Green, indicating that $3,738.27 was in the account at Wachovia Bank in Raleigh, NC. A motion was made by Billy Nelson, a second by Doug Chamblee to accept the treasurer's report. It passed.

Item 2: Since the minutes were distributed to the general membership, Chairman Lipke requested a motion to accept the minutes as printed. The motion was made by Carl Hoveland and seconded by Wilfred McMurphy. Motion passed.

NEW BUSINESS

Item 1: A report was made by the Nominations Committee composed of Billy Nelson, Chairman; Carl Hoveland, and Wilfred McMurphy. They placed the name of Dr. R.S. Kalmbacher for the positin of Chairman-elect. Ken Quesenberry moved that Kalmbacher be elected by acclamation and the motion was seconded by J.C. Burns. Kalmbacher was elected by acclamation.

Item 2: The Resolution Committee read a report commending the staff and administration of Clemson University. A copy of the resolution is attached.

Item 3: Special resolutions concerning the efforts of Bill Knight and W.A. Cope were read. It was suggested that these resolutions be included in the minutes. However, D.S. Chamblee requested that the secretary decide whether such special recognition had been kept with the minutes in the past. Lipke requested that the secretary review the minutes for previous years, and then make a decision about whether these two special resolutions should be included.

Item 4: There was some discussion about the mail list, and in general, it was decided it should include everyone, plus administrators, who has participated in SPFCIC for the past 3-5 years. The proceedings would be mailed only to participants and to libraries, etc.

Item 5: The group was notified of the invitation from Arkansas for the 1989 meeting.

Item 6: The gavel was passed from Hagen Lipke to Don Ball. The meeting was adjourned.

Respectively submitted,

James T. Green, Jr.
Secretary/Treasurer

MINUTES OF THE 43RD SPFCIC EXECUTIVE COMMITTEE

Time: April 21, 1987 8 p.m.
Clemson, South Carolina

People present: Hagen Lipke, Norm Taylor, G.E. Brink, Wilfred McMurphy, Don Ball, A.M. Thro, Gary Peterson, Werner Essig, and J.T. Green

Item 1: A treasurer's report was given and accepted. Balance is $3,738.27.

Item 2: Norm Taylor from the University of Kentucky indicated that next year's meeting would be around May 10-15 in Lexington. It was suggested that the meeting be advertised in the Agronomy News and The Forage and Hay Grower magazine.

Item 3: Don Ball indicated that the resolution committee had developed a report to be presented at the general session.

Item 4: The nominating committee had made a decision about the chairman-elect and it will be reported at the general session. A letter from the University of ARkansas was read, which invited the group to meet in Little Rock in 1989. A motion was made and seconded to accept the invitation. It passed.

Item 5: Chairman Lipke suggested that Dave Belesky take over the responsibilities of mailing the proceedings. This is the Proceedings Coordinator position vacated by John Miller in Sepetember, 1986. It was moved and seconded that he be accepted. The motion passed.

Item 6: There was some discussion about maintaining a current mail list. Jim Green suggested that the current list be sorted according to state and that the names be purged by an individual from the respective states. Some general guidelines will be sent out with the list so that the state representative can decide how to purge the list.

Item 7: Jim Green suggested that a calendar of events for the organization be developed such that everyone responsible for program development and organizational correspondence have a timetable to assist in effective communication among the membership. Lipke mentioned that December, 1987 was a target date for receiving ideas from the Work Group Program Chairman. Since there was considerable overlap of topics in the Work Group programs this year, it was decided that more effective communication among the Work Group Chairman would be necessary. Lipke agreed to facilitate that effort for 1988.

Respectively submitted,

James T. Green, Jr.,
Secretary/Treasurer

FORAGE BREEDERS WORK GROUP BUSINESS MEETING

The meeting was called to order by the president Dr. Ann M. Thro. The minutes from last year's meeting were approved as read.

Nominations were requested for secretary for the 1988 meetings. Dr. J. A. Mosjidis nominated Dr. D. Baltensperger. The nomination was seconded and, with no further nominations, Dr. Baltensperger was pronounced elected by acclamation.

Next year's meeting was announced to be Lexington, Kentucky.

Mr. Gil Lovell reported that last five years 9400 packages of seeds of legume varieties were distributed. The break down of this figure was as follows: annual clovers 3643, alfalfa 1665, red clover 1437, lespedeza and vetch 1013, and birdsfoot trefoil 615. Requests for seeds begin early Spring and continue in late July and August, thus, Mr. Lovell asked the coordinators for each test to have the seeds of all the species sent to him by June of each year. Mr. Lovell also requested the coordinators to review the management for each species so that plot sizes and amount of seed per plot would be included. Dr. K. Quesenberry made the statement that the regional legume variety tests have been a valuable activity that needed the support of everybody. He specifically asked that all new varieties be sent to Mr. Lovell so that they could be tested in the region.

President Thro requested program ideas for the next year's meeting at which she will be the president.

Dr. D. Timothy stated that the forage breeders group should indicate the needs on germoplasm collection, evaluation, and enhancement to the Crop Advisory Committees (CAC), so that money would be allocated for this purpose. Dr. Elgin said that the CAC were receptive to good ideas and that we should provide them regardless of money allocations.

President Thro asked for the names of the officers of the CAC. Dr. K. Asay (Logan, Utah) is the chairman of the committee for grasses and Dr. Dick Smith is the head of the CAC for clover and special purpose legumes.

Meeting was adjourned by motion, seconded, and passed.

Jorge A. Mosjidis,
Secretary

ECOLOGY AND PHYSIOLOGY WORK GROUP BUSINESS MEETING

The meeting was called to order by Dr. Geoff Brink. The first order of business was to nominate and elected a secretary. Dr. Richard Joost was nominated and elected by acclamation. The officers of the work group for the 1987-88 year are Dr. Vivian Allen (VPI, chairperson and program coordinator for the 1988 meeting at Lexington), Dr. Lynn Sollenberger (Univ. of Florida, Chairman elect), and Dr. Joost (LSU, Secretary).

Suggestions for session theme for the 1988 meeting were received from the floor and discussed. Two potential themes were suggested. These were a) forage establishment under adverse conditions and b) utilization of forages by horses. The latter would likely be most appropriate in a combined session with the utilization workgroup.

There was no additional new business, and the meeting was adjourned.

L. E. Sollenberger
Secretary

FORAGE UTILIZATION WORK GROUP MEETING

The meeting was called to order by President H.W. Essig at the Ramada Inn, Clemson, South Carolina on 21 April 1987. The individuals in attendance introduced themselves, stating their location, job assignment and/or area of work or interest.

A motion was made and seconded to dispense with the reading of the minutes of the 1986 business meeting in Athens, Georgia. The Noinating Committee presented Steve Schmidt, Department of Animal and Dairy Science, Auburn University as Secretary Elect. A motion was made and seconded that he be accepted by acclamation. He was unanimously accepted.

President Essig opened the floor for suggested topics during the 1988 meeting. These suggestions were offered:

1. Advantages/disadvantages of techniques/methods for determing botanical composition.
2. Statistical designs for grazing studies.
3. Nutrient flow through the animal in a grazing situation.
4. Utilization of modeling in intense grazing scenarios.
5. Micro computer demonstration of forage-beef models.

John Stuedemann briefly discussed the possibility of a joint session with the Ecology and Physiology work group or the possibility of individual meetings and a joint session.

President Essig requested that topic suggestions for the 1988 meeting could be sent to Dr. John Stuedemann, Southern Piedmont Conservation Research Center, P. O. Box 555, Watkinsville, GA 30677 or by phone: (404) 769-5631.

The 1988 meeting will be at the University of Kentucky and the 1989 meeting will be at the University of Arkansas, Fayetteville.

The motion was made and seconded to adjourn.

The following is a summary of responses to the questionaire on program topics.

A. Expanding grass (bermuda) and legume grazing season.
B. Optimizing quality of grazed bermudagrass.
C. Use of visual estimate methods and NIRS in behavioral and composition measurements.
D. Micro-computer model simulation.
E. Differential performance of various classes of livestock on the same forage source.
F. Statistical design for cow-calf and backgrounding operations.
G. Specific decision making processes while using rotation grazing, i.e. projection methods, planning procedures, etc.

Lance M. Tharel
Secretary, 1987

SOUTHERN PASTURE AND FORAGE CROP IMPROVEMENT CONFERENCE

1986 FINANCIAL STATEMENT

		Income or Return	Expense	Balance
5-20-86	Transfer of funds to N.C. (From Wauchula State Bank, FL)	3171.33		
6-10-86	Deposit of surplus seed money from GA	1992.15[1]		
	John Miller-stamps Balance of stamps not used	25.38	96.00	
	Interest earned in 1986	143.99		
	Interest earned in Jan-April 4, 1987	72.94		
12-17-86	David Belesky, Postal Permit		500.00	
	Plaques for past chairmen		71.82	
1-27-87	Bill Stringer-Seed Money Clemson, SC		1000.00	
Totals as of April 4, 1987		5406.09	1667.82	3738.27

[1] 42nd Meeting - jointly held with AFGC in GA.

Contributions & exhibits	$ 4,964.75
Registration	15,682.00
Interest	132.98
Receipts	20,779.73
Expenses	15,132.67
Surplus	$ 5,647.06

The surplus was divided (1992.45 to SPFIC, remainder to AFGC)

REGISTRANTS 1987

Curtis Absher
811 Ag. Sc. So.
University of Kentucky
Lexington, KY 40546

Montgomery W. Alison, Jr
University of Georgia
3111 Plant Sci. Bldg.
Athens, GA 30602

Martin Arechavaleta
Agronomy Department
University of Georgia
Athens, GA 30602

John L. Artz
5697 Rayburn Avenue
Alexander, VA 22311

Pat Bagley
Rosepine Res. Stn.
P. O. Box 26
Rosepine, LA 70659

Don Ball
Extension Hall
Auburn University
Auburn, AL 36849

David D. Baltensperger
304 Newell Hall
University of Florida
Gainesville, FL 32611

D. P. Belesky
USDA-ARS
P. O. Box 555
Watkinsville, GA 30677

Joe Bouton
Department of Agronomy
3111 Miller Plant Science Bldg
University of Georgia
Athens, GA 30602

David L. Bransby
Dept. of Agronomy & Soils
201 Funchess Hall
Auburn University
Auburn, AL 36849

Geoff Brink
P. O. Box 5367
Mississippi State, MS 39762

Bobby G. Brock
Rm. 535 Fed. Bldg.
310 New Bern Ave.
Raleigh, NC 27601

William A. Brock
Coastal Plain Branch Exp. Stn.
Route 2, Box 150
Newton, MS 39345

R. Harold Brown
Agronomy Dept.
University of Georgia
Athens, GA 30602

William F. Brown
AREC-One
Route 1, Box 62
Ona, FL 33865

E. Charles Brummer
3111 Miller Plant Sciences
Department of Agronomy
Athens, GA 30602

Joseph C. Burns
1119 Williams Hall
North Carolina St. Univ.
Dept. Crop Science
Raleigh, NC 27695

Joe D. Burns
University of Tennessee
P. O. Box 1071
Knoxville, TN 37901

George Byrd
3111 Miller Plant Sciences
Agronomy Department
University of Georgia
Athens, GA 30602

Scott Carr
276 Animal Sciences
VA Tech
Blacksburg, VA 24061

Douglas S. Chamblee
3359 Hampton Road
Raleigh, NC 27695

Carroll G. Chambliss
304 Newell Hall
University of Florida
Gainesville, FL 32611

G. M. Clary
Dept. Ag. Econ. & Rural Soc.
Clemson University
Clemson, SC 29634

Michael Collins
N222P Agr. Sci. Bldg.-N
University of Kentucky
Lexington, KY 40546-0091

D. L. Cross
Department of Animal Science
Clemson University
Clemson, SC 29634

Suzan S. Croughan
P. O. Box 1429
Crowley, LA 70527

R. L. Dalrymple
P. O. Box 2180
Ardmore, OK 73402

Jose P. DeBattista
3111 Miller Plant Sciences
Department of Agronomy
Athens, GA 30602

Algie Denham
105 Mauldin Drive
Alpharetta, GA 30201

Howard Van Dijk
P. O. Box 2377
Sumter, SC 29151-2377

Jim W. Dobson
GA Mtn Exp. Stn.
Route 1, Box 1005
Blairsville, GA 30512

Wade F. Faw
246 Rue de LaPlace
Baton Rouge, LA 70810

Michael D. Hall
Route 5, Box 354A
Abbeville, SC 29620

Greg Durham
University of Georgia
Department of Agronomy
3111 Miller Plant Sciences
Athens, GA 30602

Harland Feese
6625 Corners Parkway
Suite 110
Norcross, GA 30092

Wayne Hanna
USDA-ARS
Coastal Plain Stn.
Tifton, GA 31793

Keith Edmisten
Agronomy Department
VPI&SU
Blacksburg, VA 24061

Dwight S. Fisher
Crop Science Department
Box 7620
N. C. State University
Raleigh, NC 27695-7620

Gène Hardee
Room 950
1835 Assembly Street
Columbia, SC 29201

Eleanor E. Eggleston
1401 Ellison Road
Columbia, SC 29206

R. E. Franklin
Department of Agronomy & Soils
Clemson University
Clemson, SC 29634

R. L. Harwell
Dept. Ag. Econ. & Rural Soc.
Clemson University
Clemson, SC 29634

James Elgin
USDA/ARS
Bldg. 005, Room 214
Beltsville, MD 20705

Maurice H. Frere
So. Piedmont Center
P. O. Box 555
Watkinsville, GA 30677

Rod Heitschmidt
Box 1648
Vernon, TX 76384

Mike Ellsbury
Forage Res. Unit
USDA-ARS
P. O. Box 5367
Mississippi State, MS 39762

Henry Fribourg
Department of Plant
& Soil Science
P. O. Box 1071
Knoxville, TN 37901

Nick Hill
Department of Agronomy
University of Georgia
Miller Plant Sciences
Athens, GA 30602

H. W. Essig
Animal Science Department
Mississippi St. University
Mississippi State, MS 39762

Burke Garrette
206 Albermarle Place
Macon, GA 31204

Howard H. Hiller
P. O. Box 995
Pickens, SC 29671

Mike Evans
2431 Linden Lane
Silver Spring, MD 20910

Roger N. Gates
Iberia Res. Stn.
P. O. Box 466
Jeanerette, LA 70544

Ray Holliday
P. O. Box 160
Newberry, SC 29108

Gerald W. Evers
P. O. Box 728
Angleton, TX 77515

James T. Green
Box 7620
Raleigh, NC 27695-7620

C. E. Hood
Dept. of Agricultural Eng.
Clemson University
Clemson, SC 29634

Tim Fairbrother
Crop Science Lab
P. O. Box 5367
Mississippi State, MS 39762

Keith Hall
P. O. Box 149
Chesterfield, SC 29709

Carl S. Hoveland
Agronomy Department
University of Georgia
Athens, GA 30602

William Huber
Agronomy Department
University of Georgia
Athens, GA 30602

L. W. Hudson
Animal Science Department
Clemson University
Clemson, SC 29634

Mark A. Hussey
Rm. 430 Soil & Crop Sciences
Texas A & M University
College Station, TX 77843

John Irwin
219 Laurens Street
Laurens, SC 29630

Roscoe L. Ivy
P. O. Box 124
Prairie, MS 39756

Tom Jenkins
Animal Science Department
Clemson University
Clemson, SC 29634

Su Jiakai
% H. W. Youngberg
Crop Science Department
Oregon State University
Corvallis, OR 97331

Mark Johnson
Sch. For. Wild. Fish.
LSU
Baton Rouge, LA 70817

Troy Johnson
110 Frontier Ct.
Athens, GA 30602

Jim Jones
P. O. Box 640
Abbeville, SC 29620

Richard Joost
Agronomy Department
104 M. B. Sturgis
LSU
Baton Rouge, LA 70803

Rob Kalmbacher
Route 1, Box 62
Ona AREC
Ona, FL 33865

David Kee
Auburn University
201 Funchess Hall
Agronomy & Soils Department
Auburn, AL 36849

Lee Keese
P. O. Box 1797
Anderson, SC 29622

Ahmad Khalilian
Edisto Res. & Ed. Center
Box 247
Blackville, SC 29817

Lamar Kimbrough
Box 299
Bamberg, SC 29003

Krista H. Lake
P. O. Box 299
Bamberg, SC 29003

Kevin Lewis
2431 Linden Lane
Silver Spring, MD 20910

Hagen Lippke
P. O. Box 1797
Anderson, SC 29622

Ernest Locke
P. O. Box 1797
Anderson, SC 29622

Gil Lovell
S. Reg. P. I. Stn.
Georgia Exp. Stn.
Experiment, GA 30212

A. G. Matches
Dept. Plant & Soil Science
Texas Tech University
Lubbock, TX 79413

E. F. McClain
Agronomy & Soils Department
Clemson University
Clemson, SC 29634

Jim McKenna
Agronomy Department
VPI & SU
Blacksburg, VA 24061

W. E. McMurphy
OSU
Agronomy Department
Stillwater, OK 74078

Paul Mislevy
Agr. Research Center
Box 62
Ona, FL 33865

Ronald L. Mitchell
P. O. Box 2180
Ardmore, OK 73402

Jorge A. Mosjidis
Agronomy Department
Auburn University
Auburn, AL 36849

J. Paul Mueller
Box 7620
N.C. State University
Raleigh, NC 27695-7620

Billy D. Nelson
530 Heyward Green Drive
Franklinton, LA 70430

Tim Osborn
Dept. of Animal & Dairy Sci.
Auburn University
Auburn, AL 36849

John C. Pardue, Jr
P. O. Box 1005
Conway, SC 29526

David Parker
P. O. Box 700
Gaffney, SC 29340

Jeff Pedersen
Dept. Agronomy & Soils
Auburn University
Auburn, AL 36849

Gary A. Pederson
Forage Research Unit
P. O. Box 5367
Mississippi State, MS 39762

Julio Cesar Petersen
E102 University Village
Athens, GA 30605

B. W. Pinkerton
Agronomy & Soils Department
Clemson University
Clemson, SC 29634

Hugh W. Plumlee
Route 5, Box 48-N
Berryville, AR 72616

Gordon M. Prine
304 Newell Hall
Agronomy Department
University of Florida
Gainesville, FL 32611

Ken Quisenberry
2183 McCarty Hall
University of Florida
Gainesville, FL 32611

Sharron Quisenberry
405 Life Sciences Bldg.
Entomology Department
LSU
Baton Rouge, LA 70803

John Reynolds
Plant & Soil Sci. Dept.
University of Tennessee
P. O. Box 1071
Knoxville, TN 37901

Harold B. Rice
U.K. Ribinson Substation
Quicksand, KY 41363

J. S. Rice
Agronomy & Soils Department
Clemson University
Clemson, SC 29634

William R. Riley
168 Habersham Drive
Athens, GA 30606

Donald Robinson
Agronomy Department
LSU
Baton Rouge, LA 70803

Jack Ruff
P. O. Box 400
Walhalla, SC 29691

Earlene A. Rupert
Agronomy & Soils Department
Clemson University
Clemson, SC 29634

Tommy G. Sanders
Route 2, Box 150
Newton, MS 39345

Steve Schmidt
Dept. Animal & Dairy Sci.
Auburn University
Auburn, AL 36849

Dwight Seman
Box 555
Watkinsville, GA 30677

Malcolm R. Siegel
Plant Pathology Dept.
University of Kentucky
Lexington, KY 40546

G. C. Skelley
Animal Science Dept.
Clemson University
Clemson, SC 29634

S. Ray Smith
Agronomy Dept.
3111 Miller Plant Sciences
University of Georgia
Athens, GA 30602

A. W. Snell
College of Agricultural Sci.
104 Barre Hall
Clemson University
Clemson, SC 29634

L. E. Sollenberger
Animal Nutrition Lab
University of Florida
Gainesville, fl 32611

Bob Stephenson
AREC-Ona
Route 1, Box 62
Ona, FL 33865

Bill Stringer
Agronomy & Soils Dept.
Clemson University
Clemson, SC 29634

John Stuedemann
USDA-ARS
P. O. Box 555
Watkinsville, GA 30677

Mark J. Talbert
P. O. Box 329
Winnsboro, SC 29180

Norman L. Taylor
Dept. of Agronomy
Agr. Sci. Bldg. N
University of Kentucky
Lexington, KY 40546

Thomas Terrill
175 Buena Vista Ave.
Athens, GA 30601

Lance M. Tharel
USDA-ARS
Route 2, Box 144-A
Booneville, AR 72927

C. E. Thompson
Animal Science Dept.
Clemson University
Clemson, SC 29634

A. M. Thro
Agronomy Dept.
LSU
Baton Rouge, LA 70803-2110

David H. Timothy
Crop Science Dept.
N.S. State University
Raleigh, NC 27695-7620

D. J. Undersander
Edisto Res. & Educ. Center
Box 247
Blackville, SC 29817

O. P. Vadhwa
P. O. Box 60
Alcorn State University
Lorman, MS 39096

H. W. Webster
Animal Science Dept.
Clemson University
Clemson, SC 29634

Harlan E. White
419 Smyth Hall
VPI&SU
Blacksburg, VA 24061

Stanley R. Wilkinson
USDA-ARS
P. O. Box 555
Watkinsville, GA 30677

E. Darrell Williams
Sumter Co. Extension
P. O. Box 218
Bushnell, FL 33513

Mimi J. Williams
USDA-ARS-STARS
P. O. Box 246
Brooksville, FL 34298

Gary Windham
P. O. Box 5367
Mississippi State, MS 39762

Dale Wolf
Agronomy Dept.
VPI&SU
Blacksburg, VA 24061

Michael Worrell
Edisto Res. & Educ. Center
Box 247
Blackville, SC 29817

R. E. Wright
Dept. Dairy Science
Clemson University
Clemson, SC 29634